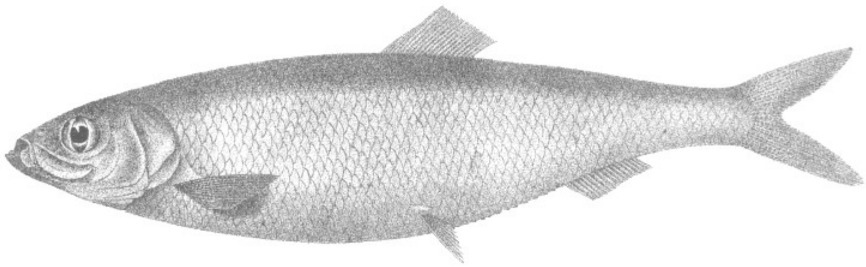
FSS Survey Series: 2018/04

Celtic Sea Herring Acoustic Survey
Cruise Report 2018

08 - 28 October, 2018



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Department of Agriculture, Food and the Marine

An Roinn Talmhaíochta, Bia agus Mara

EUROPEAN MARITIME AND FISHERIES FUND

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1 Introduction

In the southwest of Ireland and the Celtic Sea (ICES Divisions VIIaS, g & j), herring are an important commercial species to the pelagic and polyvalent fleet. The local fleet is composed of dry hold polyvalent vessels and a smaller number of large purpose built refrigerated seawater vessels (RSW). The stock is composed of both autumn and winter spawning components with the latter dominating. The fishery targets pre-spawning and spawning aggregations in Q3-4. The Irish commercial fishery has historically taken place within 1-20nmi (nautical miles) of the coast. Since the mid-2000s RSW fleet have actively targeted offshore aggregations migrating from summer feeding in the south Celtic Sea. In VIIj, the fishery is traditionally active from mid-November and is concentrated within several miles of the coast. The VIIaS fishery peaks towards the year end in December, but may be active from mid-October depending on location. In VIIg, along the south coast herring are targeted from October (offshore) to January at a number of known spawning sites and surrounding areas. Overall, the protracted spawning period of the two components extends from October through to February, with annual variation of up to 3 weeks. Spawning occurs in successive waves in a number of well known locations including large scale grounds and small discreet spawning beds. Since 2008 ICES division VIIaS (spawning box C) has been closed to fishing for vessels over 15m to protect first time spawners. For those vessels less than 15m a small allocation of the quota is given to this ‘sentinel’ fishery operating within the closed area.

The stock structure and discrimination of herring in this area has been investigated recently. Hatfield et al. (2007) has shown the Celtic Sea stock to be fairly discrete. However, it is known that fish in the eastern Celtic Sea recruit from nursery areas in the Irish Sea, returning to the Celtic Sea as young adults (Brophy et al. 2002; Molloy et al., 1993). The stock identity of VIIj herring is less clear, though there is evidence that they have linkages with VIIb and VIaS (ICES, 1994; Grainger, 1978). Molloy (1968) identified possible linkages between young fish in VIIj and those of the Celtic Sea herring. For the purpose of stock assessment and management divisions VIIaS, VIIg and VIIj have been combined since 1982.

For a period in the 1970s and1980s, larval surveys were conducted for herring in this area. However, since 1989, acoustic surveys have been carried out, and currently are the only tuning indices available for this stock. In the Celtic Sea and VIIj, herring acoustic surveys have been carried out since 1989. Since 2004 the survey has been fixed in October and carried out onboard the RV *Celtic Explorer.*

Survey design and geographical coverage have been modified over the time series to adapt to changes in stock size and behaviour. Since 2016, the wider core distribution area has been surveyed by means of two independent surveys and supplemented with small high resolution adaptive surveys focusing on areas of high abundance.

2 Materials and Methods

2.1 Scientific Personnel

Leg	Leg 1	Date	Leg 2	Date
Start	Galway	08.10.18	Cork	18.10.18
End	Cork	18.10.18	Galway	28.10.18

Organisation	Name	Name	Capacity
FEAS	Ciaran O'Donnell	Ciaran O'Donnell	Acou (Chief Sci)
FEAS	Michael O'Malley	Tobi Rapp	Acou
FEAS	Graham Johnston	Graham Johnston	Acou
FEAS	Sinead O'Brien	Sinead O'Brien	Acou
FEAS	Ian Murphy	Ian Murphy	Bio (Deck Sci)
FEAS	Eugene Mullins	Karl Bentley	Bio
FEAS / NUIG	Tobi Rapp	Sophia Wassermann	Bio
FEAS / Uni Swan	Dermot Fee	Nick Fleming	Bio
FEAS		Michael Gras	
IWDG	Sean O'Callaghan	Sean O'Callaghan	MMO
IWDG		Andrea Fariñas Bermejo	MMO
GMIT	Conall Hamill	Conall Hamill	SBO
GMIT	Heidi Acampora	Sally O'Meara	SBO
MFRI		Mary Ontomwa	MFRI, Kenya
MFRI		Noah N Ngisiang'e	MFRI, Kenya
IS&WFPO	John O'Regan	John O'Regan	Industry Obs

*SBO- Seabird observer, MMO- marine mammal observer

2.2 Survey Plan

2.2.1 Survey objectives

The primary survey objectives are listed below:

- Carry out a two phase survey cruise track covering the core survey area
- Investigate high abundance herring aggregations using adaptive survey techniques.
- Collect biological samples from directed trawling on insonified fish echotraces to determine age structure and maturity state of the herring stock
- Determine an age stratified estimate of relative abundance of herring within the survey area (ICES Divisions VIIj, VIIg and VIIaS)
- Determine estimates of biomass and abundance for sprat within the survey area
- Collect physical oceanography data from vertical profiles from a deployed sensor array
- Use the EM 2040 Bathymetric multibeam to map the extent of herring aggregations during adaptive surveys
- Survey by visual observations marine mammal and seabird abundance and distribution

2.2.2 Area of operation

The autumn 2018 survey covered the area from Mizen Head and extended along the south coast into the Celtic Sea (Divisions VIIj, VIIg & VIIaS), see Figure 1. The survey worked in an easterly direction covering the larger core survey area during the first pass before turning westwards to complete the second pass using interlaced transects.

The survey was broken into two components. The first used a double survey approach to contain the stock within the core survey area. The second adaptive component focused on high abundance areas of herring identified during the core surveys using higher intensity sampling effort (transect spacing).

2.2.3 Survey design

2.2.3.1 Core survey

A change in survey design was implemented in 2016 by consolidating all existing strata into a single core survey stratum. This broad scale survey composed of 8 nmi (nautical miles) spaced transects and progressed from west to east (Pass 2). A second pass was then carried from east to west (Pass 1). Survey transects for each pass were set at 8 nmi and offset, resulting in a transect interlacing and an effective coverage of the grounds at a 4 nmi resolution.

A parallel transect design was applied with transects running perpendicular to the coastline and lines of bathymetry where possible. Offshore extension reached up to 90 nmi. Transect start points within each stratum are randomised each year within established baseline stratum bounds.

In total the core surveys accounted for 2,311 nmi of transects covering an area of over 19,347 nmi².

2.2.3.2 Adaptive survey

Adaptive surveys were carried out in high abundance areas identified during the core survey. Candidate areas were identified from positional data from fishing activities during the co-occurring offshore fishery.

Each candidate area was scouted to determine geographical extent of target aggregations where possible. A survey plan was then designed using parallel transects running perpendicular to the lines of bathymetry. Transect spacing is determined on a survey basis and uses a balance of time available and area coverage to achieve the high resolution of sampling effort. The EK60 single beam data is supplemented with EM2040 multibeam systems were run in parallel to provide quantitative and spatial data respectively. Survey design followed methods described in Simmonds and MacLennan (2005) for adaptive surveys. Individual transects were run in parallel crossing the extent of the herring aggregation with the end point determined when no further herring were observed for 0.5 nmi.

Directed fishing trawls and in-trawl optics were used to determine echotrace identification as applied during routine surveying operations.

Combined, the three adaptive surveys accounted for 459 nmi of transects covering an area of 3,304 nmi².

2.3 Equipment and system details and specifications

2.3.1 Acoustic array

Equipment settings for the acoustic equipment were determined before the start of the survey program and were based on established settings employed by FEAS on previous surveys (O'Donnell *et al.,* 2004). The acoustic settings for the EK60 38 kHz transducer are shown in Table 1.

Acoustic data were collected using the Simrad EK60 scientific echosounder. The Simrad split-beam transducers are mounted within the vessel's drop keel and lowered to the working depth of 3.3m below the vessel's hull or 8.8m sub surface. Four operating frequencies were used during the survey (18, 38, 120 and 200 kHz) for trace recognition purposes, with the 38 kHz data used to generate the abundance estimate.

While on survey track the vessel is normally propelled using DC twin electric motor propulsion system with power supplied from 1 main diesel engine, so in effect providing "silent cruising" as compared to normal operations (ICES 2002). During fishing operations normal two-engine operations were employed to provide sufficient power to tow the net.

For the EM2040 bathymetric multibeam a manual fixed angular coverage was used (65° opening angle) to standardise the volume of water sampled. Pulse type and ping rate were set to auto to optimise data acquisition and the sampling frequency was set at 300 kHz to minimise interference on the EK60. The ping rate on the EK60 was maintained at 3 pings per second while the EM2040 auto setting produced a ping rate of approximately 3.5 pings per second.

2.3.2 Calibration of acoustic equipment

A calibration of the EK60 was carried out in Dunmanus Bay on the 26th of October at the end of the survey and in daylight hours following methods described by Demer *et al.* (2015). Calibration results and settings are provided in Table 1.

2.4 Survey protocols

2.4.1 Acoustic data acquisition

The "RAW files" were logged via a continuous Ethernet connection to the vessels server and the ER60 hard drive as a backup in the event of data loss. In addition, as a further back up a hard copy was stored on an external hard drive. Myriax Echoview® Echolog (Version 7) live viewer was used to display the echogram during data collection to allow the scientists to scroll through echograms noting the locations and depths of fish shoals. A member of the scientific crew monitored the equipment continually. Time and location (GPS position) data was recorded for each transect within each strata. This log was used to monitor the time spent off track during fishing operations and hydrographic stations plus any other important observations.

2.4.2 Biological sampling

A single pelagic midwater trawl with the dimensions of 19 m in length (LOA) and 6 m at the wing ends and a fishing circle of 330 m was employed during the survey (Figure 15). Mesh size in the wings was 3.3 m through to 5 cm in the cod-end. The net was fished with a vertical mouth opening of approximately 9m, which was observed using a cable linked Simrad FS70 netsonde. The net was also fitted with a Scanmar depth sensor. Spread between the trawl doors was monitored using Scanmar distance sensors, all sensors being configured and viewed through a Scanmar Scanbas system.

All components of the catch from the trawl hauls were sorted and weighed; fish and other taxa were identified to species level. Fish samples were divided into species composition by weight. Species other than the herring were weighed as a component of the catch. Length frequency and length weight data were collected for each component of the catch. Length measurements of herring, sprat and pilchard were taken to the nearest 0.5 cm below. Age, length, weight, sex and maturity data were recorded for individual herring within a random 50 fish sample from each trawl haul, where possible. All herring were aged onboard. The appropriate raising factors were calculated and applied to provide length frequency compositions for the bulk of each haul.

Decisions to fish on particular echo-traces were largely subjective and an attempt was made to target marks in all areas of concentration not just high density schools. No bottom trawl gear was used during this survey. However, the small size of the midwater gear used and its manoeuvrability in relation to the vessel power allowed samples at or below 1 m from the bottom to be taken in areas of clean ground.

2.4.3 Oceanographic data collection

Oceanographic stations were carried out during the survey at predetermined locations along the track. Data on temperature, depth and salinity were collected using a calibrated Seabird 911 sampler at 1 m subsurface and 3 m above the seabed.

2.4.4 Marine mammal and seabird observations

2.4.4.1 Marine Mammal sighting survey

During the survey an observer kept a daylight watch on marine mammals from the crow's nest (18 m above sea level) when weather allowed or from the bridge (11 m).

During cetacean observations, watch effort was focused on an area dead ahead of the vessel and 45° to either side using a transect approach. Sightings in an area up to 90° either side of the vessel were recorded. The area was constantly scanned during these hours by eye and with binoculars. Ship's position, course and speed were recorded, environmental conditions were recorded every 15 minutes and included, sea state, visibility, cloud cover, swell height, precipitation, wind speed and wind direction. For each sighting the following data were recorded: time, location, species, distance, bearing and number of animals (adults, juveniles and calves) and behaviour. Relative abundance (RA) of cetaceans was calculated in terms of number of animals sighted per hour surveyed (aph). RA calculations for porpoise, dolphin species and minke whales were made using data collected in Beaufort Sea state ≤ 3. RA calculations for large whale species were made using data collected in Beaufort Sea state ≤ 5.

2.4.4.2 Seabird sighting survey

A standardized line transect method with sub-bands to allow correction for species detection bias and 'snapshots' to account for flying birds was used (following recommendations of Tasker *et al.* 1984; Komdeur *et al.*1992; Camphuysen *et al*. 2004), as outlined below.

Two observers (a primary observer and a primary recorder, who also acted as a secondary observer), in rotation from a pool of three surveyors, were allocated to survey shifts of two hours, surveying from 08.00 (or first light) to 18.00 hours (dusk) each day. Environmental conditions, including wind force and direction, sea state, swell height, visibility and cloud cover, and the ship's speed and heading were recorded at 2-hourly intervals during surveys. In the intervening time, any changes to environmental conditions were also noted, so that a discreet set of environmental conditions was obtained for each 5-minute interval. No surveys were conducted in conditions greater than sea state 5, when high swell made working on deck unsafe or when visibility was reduced to less than 300 m.

The seabird observation platform was the wheelhouse deck, which is 10.5m above the waterline and provided a good view of the survey area. The survey area was defined as a 300m wide band operated on one side (in a 90° arc from bow to beam) and ahead of the ship. This survey band was sub-divided (A = 0-50 m from the ship, B = 50-100 m, C = 100-200 m, D = 200-300 m, E > 300 m) to subsequently allow correction of differences in detection probability with distance from the observer. A fixed-interval range finder (Heinemann 1981) was used to periodically check distance estimates. The area was scanned by eye, with binoculars used only to confirm species identification.

All birds seen on the water within the survey area were counted, and those recorded within the 300 m band, were noted as 'in transect'. All flying birds within the survey area were also noted, but only those recorded during a 'snapshot' were regarded as 'in transect'. This method avoids overestimating bird numbers in flight (Tasker *et al*. 1984). The frequency of the snapshot scan was ship-speed dependent, such that they were timed to occur at the moment the ship passed from one survey block (300 m x 300 m) to the next. Survey time intervals were set at 5 minutes. Additional bird species observed outside the survey area were also recorded and added to the species list for the research cruise, but these will not be included in maps of seabird abundance or density.

On acoustic survey transects the vessel had an average speed of 10 knots, while speed was reduced to 4 knots for trawling effort. Tows lasted around 45 minutes and were mostly separated by extended sessions of steaming at 10 knots, so that few birds were attracted to the ship. CTD stations were conducted on some transects, during which the vessel remained stationary for, on average, 18 minutes. Seabird surveying was interrupted while the ship was stationary at CTD stations and while towing since this can attract large numbers of birds. Where fish sampling operations were prolonged or at close intervals, seabird surveying was only recommenced after a period (45min – 1hr) of prolonged steaming at 10 knots, allowing the associating birds to disperse. Any bird recorded in the survey area that stayed with the ship for more than 2 minutes was regarded as being associated with the survey vessel (Camphuysen *et al.* 2004) and was coded as such (to be excluded from abundance and density calculations).

The daily total count data per day for each species is presented along with the daily survey effort. It is envisaged that this data will be analyzed in the future and the seabird abundance (birds per km traveled), and seabird density (birds per km^2) will be mapped per 1⁄4 ICES rectangle (15' latitude x 30' longitude), allowing comparison to the results of previous seabird surveys in Irish waters (e.g. Hall *et al*. in press, Mackey *et al*. 2004, Pollock *et al*. 1997). Through further analysis, species-specific correction factors will be applied to birds observed on the water. It is also hoped to combine this analysis with the results of the cetacean observation and acoustic survey. The binomial species names for the birds recorded are presented in the species accounts.

All visible marine litter was also recorded during bird observations. The litter was identified or described as accurately as possible; quantity, size and distance from the boat was noted. When possible, pictures of the objects were taken.

2.5 Analysis methods

2.5.1 Echogram partitioning

Acoustic data was backed up every 24 hrs and scrutinised using Echoview® (V 7) post processing software.

The RAW files were imported into Echoview for post-processing. The echograms were divided into transects. Echotraces belonging to target species were identified visually and echo integration was performed on the enclosed regions. The echograms were analysed at a threshold of -70 dB and where necessary plankton was filtered out by thresholding at –65 dB.

Partitioning of echograms to identify individual schools was carried out to species level where possible and mixed scattering layers where it was not possible to identify mono-specific schools. For scattering layers or mixed schools containing target species the total NASC (Nautical Area Scattering Coefficient) was split by Target strength to provide a species specific NASC value using a function within StoX.

The echogram scrutinisation process was carried out by a scientist experienced in scrutinising echograms and with the aid of accompanying trawl catch data.

The allocated echo integrator counts (NASC values) from these categories were used to estimate the herring numbers according to the method of Dalen and Nakken (1983).

The TS/length relationships used predominantly for the Celtic Sea Herring Survey are those recommended by the acoustic survey planning group based at 38 kHz (ICES, 1994):

Herring	TS = 20logL – 71.2 dB per individual (L = length in cm)
Sprat	TS = 20logL – 71.2 dB per individual (L = length in cm)
Mackerel	TS = 20logL – 84.9 dB per individual (L = length in cm)
Horse mackerel	TS = 20logL – 67.5 dB per individual (L = length in cm)
Anchovy	TS = 20logL – 71.2 dB per individual (L = length in cm)

The TS length relationship used for gadoids was a general physoclist relationship (Foote, 1987):

Gadoids	TS = 20logL – 67.5 dB per individual (L = length in cm)

2.5.2 Abundance estimate

Acoustic data were analysed using the StoX software package as adopted for all WGIPS coordinated surveys (ICES 2016). A description of StoX can be found here: http://www.imr.no/forskning/prosjekter/stox/nb-no. Estimation of abundance from acoustic surveys within StoX is carried out according to the stratified transect design model developed by Jolly and Hampton (1990).

3 Results

3.1 Celtic Sea herring stock

3.1.1 Herring biomass and abundance

Total herring biomass (TSB) and spawning stock biomass (SSB) by survey strata is provided in Table 3. The biomass presented below was determined using Pass 1 (core survey) data representing the largest geographical area surveyed.

Herring	Abund ('000)	Biomass (t)
Total stock	213,491.0	9,788.2
Spawning stock	91,735.0	7,760

3.1.2 Herring distribution

A total of 15 trawl hauls were carried out during the survey (Figure 1). Of the 15 trawl stations, herring were present in all catches, occurring in the most part as immature 0-group fish and contributing from 0.1- 80.2% by weight of bulk catch. Of this, four catches containing >50% herring (Table 2).

Core Surveys

Two core surveys were carried out; Pass 1 and Pass 2. A total of 32 echotraces were identified as herring during both passes. The highest proportion of herring echotraces was located in inshore waters between Cork Harbour and Hook Head, with a lower number widely distributed further offshore (Figure 2). Overall, the acoustic densities of herring echotraces were low and herring were most frequently observed as part of mixed species aggregations with other pelagic species including sprat, pilchard and juvenile mackerel (Figure 8a-b). Offshore, immature 0-group herring were encountered in varying number in all hauls and no mature individuals were encountered. In inshore waters (<10 nmi), seven hauls were undertaken within 10 nmi of the coast. Three hauls within this area contained the only mature herring observed during the survey (2-6 winter rings). One inshore trawl haul (Haul 12) undertaken on a medium density school and contained a highest proportion of mature herring (76% mature) observed during the survey (Figure 8c, Table 2).

In terms of effort, acoustic sampling in core areas was comparable to 2016-17.

Adaptive Surveys

Three adaptive surveys were conducted; two offshore and one inshore (Figure 3). Offshore adaptive surveys were carried out around the 'Celtic Deep/Smalls' area. Two separate surveys were carried out with a temporal separation of five days (15-16th and 20-21st October). Individual survey design used a 2 nmi transect spacing with each survey acting as a replicate using spatially interlaced transects, essentially providing a ground coverage of 1 nmi overall. No herring were observed during either offshore replicate survey. Off track scouting was undertaken in the 'Trench' area during the core surveys as aggregations were detected in this area in earlier years. However, no herring were detected during two separate searches extending to approximately 78 nmi. As no offshore aggregations were encountered the stock was considered contained within the survey area.

An inshore adaptive survey was carried out from the 24th to the 25th October, focusing on the area where the directed fishery was in operation. The initial survey was conducted from Ram Head to Ballycotton on the 24th and was followed up from the Old Head to Ballycotton the 25th. Ten herring echotraces were observed during the inshore survey and two hauls were undertaken (Haul 13 & 15). Haul 13 contained only a small proportion of herring (<1 % by weight), Table 2. Haul 15, close to Kinsale, was composed of mixed species and herring contributed 65% of the total catch, of which 46% were immature 0-1 ring herring (Figure 8d).

3.1.3 Herring stock composition

A total of 529 herring were aged from survey samples, in addition to 1,668 length measurements and 807 length-weights. Herring age samples ranged from 0-8 winter-rings (Figures 4 & 5, Tables 3 & 4). Length at age and maturity by strata are presented in Figure 1-3 in the Appendix.

Core survey

The Pass 1 survey represents the 2018 estimate based on the largest stratum area surveyed and follows procedure adopted in 2017. Pass 1 represents a total biomass of 9,788.2 t and a total abundance of 213,491,000 individuals. Age composition of Pass 1 was made up of a high proportion of immature fish (0 group) compared to recent years, representing 14% of the TSB and 51% of TSN. Of the mature fish component, three winter ring fish represent 32.4% of TSB and 12.6% of TSN, followed by one winter ring fish (31.7% biomass and 26.1% abundance), two one winter ring fish (13.7% biomass and 7.5% abundance) and four winter ring fish (7.9% biomass and 2.8% abundance). The proportion of one winter ring fish recorded as mature was 72%, rising to 99% for 2 winter ring fish and 100% maturity for 3 and over (Figure 1, Appendix 1).

Immature fish accounted over 20% (2,027.8 t) of the 9788.2 t TSB estimate.

Adaptive surveys

The inshore adaptive survey focused on a specific area from the old Head of Kinsale to Ram Head. The adaptive survey accounted for 266.4 t of total biomass and 2,999,000 individuals. Age composition was dominated by 1 winter ring fish accounting for 30.2% of total biomass and 44.6% of total abundance. Ranked second and third were the three and four winter ring fish accounting for 29.9% and 23.8% of biomass and 22.8% and 17.2% of abundance respectively.

Immature fish accounted over 4.8% (12.8 t) of the 266.4 t estimate.

3.2 Other pelagic species

3.2.1 Sprat

Sprat	Abund ('000)	Biomass (t)
Total stock	6,934.1	47,805.7

Sprat were found widely distributed throughout the survey area and sampled in 14 of 15 hauls (Figure 6, Table 2). In total, 2,344 individual length measurements and 1,256 length/weight measurements were recorded. Mean length was 9.3 cm and mean weight was 7.0 g (7.7 cm and 3.4 g in 2017). Individuals ranged from 6.5 to 13.5 cm in length and 2 to 20 g in weight. Biomass and abundance by survey strata is presented in Table 5.

A total of 505 (485 in 2017) individual sprat echotraces were identified during core surveys (Pass 2: 334 and Pass 1: 171). Distribution was comparable with recent years but with an increased abundance in the eastern survey area. This eastern distribution of sprat continued unabridged to the UK coastline (J. Vanderkooij, pers. comm.) Inshore areas (<10 nmi from coast) to the east of the 8°W line of latitude contained some significant high density aggregations as compared to offshore areas (Figures 8e, f).

Comparing inshore and offshore trawl samples, mean length and weight of sprat from inshore was slightly higher than that further offshore at 10.25cm and 8.86g compared to 9.42 cm and 6.91g respectively. Overall the most dominant size class occurred at 8.5-9 cm (7.5-8 cm in 2017) as shown in Figure 7.

3.3 Oceanography

A total of 40 CTD stations were carried out across the survey area. Surface plots of temperature and salinity are presented using 5 m and 20 m depth profiles (Figures 9 & 10), while profiles for 60 m and near bottom profiles are overlaid with sprat and herring NASC data respectively (Figures 11 & 12).

Horizontal plots of temperature and salinity at 5 and 20 m depths showed conditions were relatively uniform for surface waters above the thermocline (Figure 9 &10). The influence of riverine input is evident in surface waters at the mouth of Cork Harbour and at Youghal on the south coast. The extent of the seasonal thermocline is evident at all but the south eastern most stations when comparing deep and shallow profiles (Figures 10 & 11). Tidal mixing of the water column in the Celtic Deep area ensures all but a temporary thermocline between monthly tidal phases (O'Donnell, *unpublished data*). At 60m, the most striking feature is the temperature below the thermocline for stations north of the 51°N line of latitude exceeding 14°C (Figure 11 & 12), higher than surface waters. Bottom temperature data follows a similar pattern with higher temperatures in the northern area compared to further south. The distribution of sprat appears to be correlated with these warmer and thermal frontal boundary regions across the survey area.

3.4 Marine mammal and seabird observations

3.4.1 Marine mammal abundance and distribution survey

Survey effort

One marine mammal observer (MMO) undertook daily watches during leg 1 (8th – 18th October) but was accompanied by another MMO for leg 2 (19th – 28th October). Watches were conducted entirely from the ships crow's nest located 19m above sea level. Both MMO's were conducted watches at the same time during leg 2 where one scanned the port side and the other scanned the starboard side.

A total of 88 hrs and 2 minutes (5,282 mins) of surveying effort was completed across fourteen days where all surveying effort took place in the crow's nest given sea conditions while on effort never exceeded an unsafe level to work from the crow's nest.

Environment

A total of 302 environmental stations took place during the survey. Weather conditions were good for 36.1% of stations that were ≤ sea state 2, while 63.9% of stations were ≥ sea state 3. Swell height was recorded as being moderate (1-2m) 47.5% of the time while 28.9% of the swell was 1 or 0m in height. Heavy swell (>2m) occurred during 23.6% of surveying effort. Visibility was very good for the majority of the survey with 16-20km to the horizon recorded on 61.6% of stations while poor visibility (<1-5km) occurred 7.4% of the time spent surveying. Overall precipitation did not occur 94% of the time on effort but when it occurred rain occurred the most at 4.6% of stations while mist occurred at 1.3%. When precipitation did occur, intensity varied from 61.5% for continuous light to 23.1% for intermittent light and 15.4% for continuous heavy.

Sightings report

Six cetacean species were positively identified during the survey, they were: common dolphins, fin whales, a humpback whale, a minke whale, bottlenose dolphins and harbour porpoises. Fin whales were first recorded 38 km south of Bunmahon, Waterford on14th October off Waterford. They were not recorded inshore that day and were re-sighted when surveying to the south later in the day. All large whale sightings were made offshore for the remainder of leg 1 and the start of leg 2 but a shift in distribution was noted on the 22nd when the humpback whale was encountered along with 5 fin whales approximately 12 km southeast of Ringville, Dungarven off Waterford (Figure 13).

Common dolphins were recorded throughout the survey but displayed an eastern distribution similar to the large whales recorded. The bottlenose dolphin sightings were approximately 72.8 km south of Carnsore Point, Wexford so they may have been part of the Irish offshore population while the harbour porpoises were briefly seen while inshore off Waterford (Figure 13).

Numerous tuna (Bluefin, albacore and unidentified species) were made throughout the survey in both inshore and offshore waters from Cork to Wexford while one grey seal was sighted near Cork Harbour and an unidentified seal species was noted offshore (see Figure 14, Table 7).

A total of 92 cetacean sightings were made while on effort comprising of 944 individuals were made (Table 6). 78 tuna sightings of two identified species were also made on effort involving 290 individuals. An additional 18 off effort sightings were recorded of 6 fin whales (N = 4), 85 common dolphins (N = 8), 3 unidentified whales (N = 2). 60 unidentified dolphins (N = 2) and 7 bluefin tuna (N = 1).

The most frequently sighted and abundant species was the short-beaked common dolphin at 72% (N = 66) of all sightings and 95% (893) of individual species seen. Common dolphins were recorded on eleven of the fourteen survey days followed by fin whales on six days, unidentified dolphins and whales were seen on 3 days while the humpback whale, minke whale, harbour porpoises and unidentified small whale were present on one survey day each while on effort.

From the tuna sightings (when identification was possible), 22 sightings were of bluefin tuna (Thunnus thynnus) involving 107 individuals where group sizes ranged from 4 – 15 individuals were noted. One albacore tuna (Thunnus alalunga) sighting involving 3 individuals was also made while 55 sightings involving 180 individual tuna sp. were recorded (Table 7). One adult grey seal was observed off the Cork coast while a seal species was noted off of Wexford (Figure 14).

Fin whale sightings were primarily off the south coast of Waterford during the survey. Three juveniles and one calf were observed with adult fin whales on 4 occasions. Lateral images of the dorsal fin on both sides along with the ventral surface of the tail fluke of the humpback whale sighted confirmed that it was a known individual from the Irish humpback whale catalogue as HBIRL3 or “Boomerang”.

3.4.2 Seabird abundance and distribution survey

A total of 62 hours and 31 minutes (3751 minutes) of dedicated seabird surveys was conducted across fifteen days between 10th October and 25th October 2018. Inclement weather conditions meant that no surveys were conducted on 9th and 12th October (Storm ‘*Callum’*) and 18th October (crew change). A total of seven-point counts were made during fishing tow operations during the survey.

A cumulative total of 5097 individual seabirds of 23 species was recorded, of which 1292 were noted as ‘off survey’ (outside of dedicated survey time or associating with the vessel, including during fishing operations point counts) and as such will be excluded from future analysis of abundance and density. A synopsis of daily totals for all seabird species recorded is presented in Table 8. In addition, daily totals for twelve species of migrant terrestrial birds recorded on or around the vessel are also presented (Table 9).

4 Discussion and Conclusions

4.1 Discussion

The objectives of the survey were carried out successfully and as planned. Approximately 48 hours of weather induced downtime was recorded, including events associated with Storm '*Callum'*. Lost time was made due to the lack of trawling opportunities and this allowed for sufficient planned area coverage to be achieved.

Geographical coverage was comparable to previous years, as was survey effort (miles covered). Offshore hotspots were covered comprehensively, including the western Celtic Deep and Trench area. Reports from the demersal fleet and searching effort carried out by the commercial herring fleet substantiated survey observations regarding the lack of offshore aggregations.

Immature 0-group herring were observed across the survey area, appearing in every haul albeit in low numbers. The presence of this year class was reported further east toward the UK coast by the RV *CEFAS Endeavour as* part of the co-occurring PELTIC survey program (J. Vanderkooij, pers. comm.). Overall, the contribution of 0-group herring accounts for over 51% of the total stock abundance for the Pass 1 estimate. Within the longer time series, this signal is encouraging as a potential source of recruitment in a period of low stock abundance and persistent poor recruitment (Table 4).

Outside of the contribution of 0-group fish, observations of immature/maturing 1-winter ring herring close to the shore at this time of year is well documented and do not contribute to the main body of the spawning stock until fully recruited (>2 yrs.). The contribution of this age group to the annual estimate from this inshore area is nothing new.. In 2018, this age group represents a higher than normal proportion to the overall estimate (31.7% of TSB and 26.1% of TSN) due to the lack of larger, mature fish. The arrival of a proportion of the mature (>2 winter ring) migratory component of the stock into the inshore grounds during the survey saw focused activity in the fishery from mid to late October. An adaptive survey was carried out within this area encompassing the area of the fishery. The biomass from this adaptive survey was low; accounting for a total of 266 t. This estimate was not included as part of the total estimate for 2018 (Pass 1 only) due to geographical overlap in coverage and the potential of double counting of schools within the same area.

The spawning stock biomass (SSB) estimate in 2018 is comparable to 2017, and combined represent the lowest SSB points in the 25 year survey time series. The downward trend in the standing stock biomass has continued from a medium term high in 2011-12 and has been exacerbated by a prolonged period of poor recruitment. The absence of the offshore migratory component of the stock within the wider survey area cannot be attributed to containment as good area coverage was attained. Observations made during the WESPAS summer survey validate observations during this survey of low standing stock abundance (O'Donnell *et.al.* 2018).

Sprat biomass and distribution follows a similar pattern to previous years with schools spread widely over the Celtic Sea. As sprat show strong diel migration into surface waters at night this makes reliable acoustic measurements difficult. As the survey operates over 24 hrs estimates the annual abundance of sprat are somewhat limited in this regard.

4.2 Conclusions

- The stock was considered contained within the survey area in 2018 with no offshore herring or aggregations around the survey periphery noted. Observations from the summer WESPAS survey in agreement with low standing stock abundance.
- The contribution of 1-winter ring fish from around the around Cork Harbour area is an annual occurrence in low background numbers. In 2018, this age group represents a significant contribution to the overall biomass (31.7% of TSB and 26.1% of TSN). It is important to note that this proportion is relative to the low contribution of other age classes in the overall low abundance estimate and not a sign of a stronger than normal year class for this cohort.
- Immature fish accounted over 20.7% of the TSB and 57% of TSN. Of this, 0-group herring represented 14% of TSB and 51% of TSN, while 1-winter ring fish represented the remainder.
- The potential of a positive signal in recruitment was evident from survey catches with 0-group herring observed across the CSHAS survey area and further east into UK waters. The strength of this year class is significant in a period of prolonged poor recruitment. However, contribution of this year class will only become evident when fully recruited into the SSB over the next 2 years.
- Dominant, mature age classes within the stock are represented within the survey (3, 1 and 2 winter rings respectively). The ability to successfully track cohorts through the survey time series has been problematic and is exacerbated by continued low abundance.
- Observations during the survey are in agreement with commercial fishing effort regarding distribution of the stock. After a period of offshore searching the focus of the herring fishery moved to inshore waters.
- Since 2013 survey observations indicate that the biomass of the offshore migratory component of the stock is decreasing and this trend continues into 2018. Standing stock biomass is at the lowest level in the 25-year survey time series.
- The biomass and abundance of sprat was higher than in 2017 and more in line with the 2016 estimate. Consistency between core surveys (Pass 1 vs. Pass 2) was in close agreement providing a degree of confidence of the internal consistency of the survey. The length profile of the stock is comparable across years, with smaller length cohorts continuing to dominate.

5 Acknowledgements

We would like to thank the captains Denis Rowan and Anthony Hobin and the crew of the Celtic Explorer for their help and professionalism during the survey. We also thank John O' Regan for his expert advice on fishing operations and for liaising with the commercial fishing fleet. Many thanks also to the seabird and marine mammal survey teams, who worked tirelessly during the survey in all weathers and with great enthusiasm.

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7 Tables and Figures

Table 1. Calibration report: Simrad EK60 echosounder at 38 kHz.

Echo Sounder System Calibration

Vessel :	R/V Celtic Explorer	Date :	26.10.2018
Echo sounder :	ER60 PC	Locality :	Ireland
Type of Sphere :	WC-38,1	TS~Sphere~: -42.40 dB (Corrected for soundvelocity)	Depth(Sea flo 39 m

Calibration Version 2.1.0.12

Comments:
CSHAS. Dunmanus Bay 26.10.18

Reference Target:

TS	-42.40 dB	Min. Distance	16.00 m
TS Deviation	5.0 dB	Max. Distance	19.50 m

Transducer: ES38B Serial No. 30227

Frequency	38000 Hz	Beamtype	Split
Gain	25.65 dB	Two Way Beam Angle	-20.6 dB
Athw. Angle Sens.	21.90	Along. Angle Sens.	21.90
Athw. Beam Angle	7.03 deg	Along. Beam Angle	6.86 deg
Athw. Offset Angle	-0.01 deg	Along. Offset Angl	0.00 deg
SaCorrection	-0.63 dB	Depth	8.80 m

Transceiver: GPT 38 kHz 009072033933 2-1 ES38B

Pulse Duration	1.024 ms	Sample Interval	0.193 m
Power	2000 W	Receiver Bandwidth	2.43 kHz

Sounder Type:
EK60 Version 2.4.3

TS Detection:

Min. Value	-50.0 dB	Min. Spacing	100 %
Max. Beam Comp.	6.0 dB	Min. Echolength	80 %
Max. Phase Dev.	8.0	Max. Echolength	180 %

Environment:

Absorption Coeff.	8.9 dB/km	Sound Velocity	1509.2 m/s

Beam Model results:

Transducer Gain =	25.65 dB	SaCorrection =	-0.66 dB
Athw. Beam Angle =	6.98 deg	Along. Beam Angle =	6.92 deg
Athw. Offset Angle =	-0.04 deg	Along. Offset Angle=	-0.05 deg

Data deviation from beam model:
RMS = 0.11 dB
Max = 0.33 dB No. = 82 Athw. = -2.9 deg Along = -2.2 deg
Min = -0.33 dB No. = 370 Athw. = 2.3 deg Along = -4.4 deg

Data deviation from polynomial model:
RMS = 0.09 dB
Max = 0.25 dB No. = 82 Athw. = -2.9 deg Along = -2.2 deg
Min = -0.27 dB No. = 370 Athw. = 2.3 deg Along = -4.4 deg

Comments :
Dunmanus Bay
Wind Force : 2 kn. **Wind Direction :** N degrees
Raw Data File: E:\CE18016_CSHAS 2018\Calibration\38 kHz Cal\CSHAS 2018-D20181026-T090459.raw
Calibration File: E:\CE18016_CSHAS 2018\Calibration\38 kHz Cal\Cal 38 kHz.txt

Calibration: Ciaran O'Donnell

Table 2. Catch table from directed trawl hauls.

No.	Date	Lat. N	Lon. W	Time	Bottom (m)	Target btm (m)	Bulk Catch (Kg)	Herring %	Mackerel %	Scad %	Sprat %	Pilchard %	Others* %
1	13.10.18	51.47	-7.71	13:50	79	19	250.0	22.0	33.1	0.5	34.6		9.9
2	13.10.18	52.00	-7.50	19:24	36	10	123.5	0.9	0.5		78.5	0.2	19.9
3	14.10.18	51.79	-7.29	10:07	73	30-40	240.0	0.1	0.7	0.3	96.3		2.7
4	15.10.18	51.99	-6.86	09:35	56	40	160.0	5.2	1.3		93.2		0.3
5	15.10.18	51.62	-6.65	14:56	68	50	170.0	0.6		7.8	79.9		11.7
6	16.10.18	51.93	-6.43	14:52	60	50	190.0	2.2	1.4	7.7	88.5		0.2
7	19.10.18	51.25	-6.34	14:25	106	90	167.0	25.9	4.9	4.5	62.6		2.2
8	20.10.18	51.14	-6.78	15:43	90	90	8.1	62.8	6.4		9.8		21.0
9	21.10.18	52.09	-6.76	08:05	30	30	1000.0	0.1	2.1		97.8		
10	21.10.18	51.32	-6.96	16:33	88	88	153.9	61.6	0.1		36.2		2.0
11	22.10.18	52.02	-7.39	10:48	45	45	1000.0	11.1	12.0		76.1	0.1	0.7
12	23.10.18	51.89	-7.60	07:19	54	54	1900.0	80.2	8		11.11	1.00	0.2
13	24.10.18	51.80	-7.92	05:39	42	42	800.0	0.3	94.3		0.3	4.7	0.4
14	24.10.18	50.91	-8.23	19:55	107	107	5.8	0.2	26.8	0.9			72.1
15	25.10.18	51.63	-8.49	06:30	42	42	1400.0	65.4	34.2		0.2	0.1	0.1

Table 3. Herring biomass and abundance by strata. Highlighted strata (Pass 1) presented as total stock biomass based on largest stratum area surveyed.

Strata	Name	Type	Area (nmi²)	Transects	TSN ('000)	TSB (t)	SSN ('000)	SSB (t)	CV (Abun)
1	Pass 1	Core	8,693.2	13	213,491	9,788.2	91,735	7,760.4	49.60
2	Pass 2	Core	7,349.3	18	66,561	2,008.5	14,632	1,284.4	72.50
3	Inshore	Adpt	2,668.7	16	2,999	266.4	2,754	253.6	-
4	Smalls_1	Adpt	309.6	11	0	0	0	0	-
5	Smalls_2	Adpt	326.0	11	0	0	0	0	-
	Total		19,346.8	69	213,491	9,788	91,735	7,760	49.6

Table 4. Celtic Sea herring survey time series.

Season Age (wr)	2002 2003	2003 2004	2004 2005	2005 2006	2006 2007	2007 2008	2008 2009	2009 2010	2010 2011	2011 2012	2012 2013	2013 2014	2014 2015	2015 2016	2016 2017	2017 2018	2018 2019
0	0	24	-	2	-	1	2	239	5	0.1	31	3.8	0	0	0	0	109
1	42	13	-	65	21	106	63	381	346	342	270	697.6	41	0	125	0	56
2	185	62	-	137	211	70	295	112	549	479	856	291.4	117	40	21	6	16
3	151	60	-	28	48	220	111	210	156	299	615	197.4	112	48	43	3	27
4	30	17	-	54	14	31	162	57	193	47	330	43.7	69	41	40	7	6
5	7	5	-	22	11	9	27	125	65	71	49	37.9	20	38	36	5	0
6	7	1	-	5	1	13	6	12	91	24	121	9.8	24	7	25	4	0
7	3	0	-	1	-	4	5	4	7	33	25	4.7	7	6	5	1	-
8	0	0	-	0	-	1	-	6	3	4	23	0	17	5	6	1	-
9	0	0	-	0	-	0	-	1	-	2	3	0.2	1	0	0	0	-
Abundance	423	183	-	312	305	454	671	1,147	1,414	1,300	2,322	1,286	408	184	301	27	213
SSB	41	20	-	33	36	46	93	91	122	122	246	71	48	25	30	4	8
CV	49	34	-	48	35	25	20	24	20	28	25	28	59.1	18.4	33	NA	49.6
Design	AR	AR	-	ARS	ARS	ARS	ARS	ARS	ARS	ARS	ARS	ARS	ARM	ARM	CRM	CRM	CRM

Table 5. Sprat biomass and abundance by strata.

Strata	Name	Type	Area (nmi²)	Transects	TSN ('000)	TSB (t)
1	Pass 1	Core	8,693.2	13	6,886,165	47,523.9
2	Pass 2	Core	7,349.3	18	7,395,574	51,039.6
3	Inshore	Adpt	2,668.7	16	137,144	1,214.7
4	Smalls_1	Adpt	309.6	11	47,939	281.8
5	Smalls_2	Adpt	326.0	11	126,228	742.0
	Total		19347	69	6,934,104	47,806

Table 6. Marine mammal sightings, counts and group size ranges for cetaceans sighted.

Species common name	Scientific name	No. of sightings	No. of animals	Group size range
Short-beaked common dolphin	*Delphinus delphis*	66	893	2 - 120
Fin whale	*Balaenoptera physalus*	14	20	2 - 3
Humpback whale	*Megaptera novaeangliae*	1	1	N/A
Minke whale	*Balaenoptera acutorostrata*	1	1	N/A
Common bottlenose dolphin	*Tursiops truncatus*	1	11	N/A
Harbour porpoise	*Phocoena phocoena*	1	4	N/A
Unidentified whale	Cetacean sp.	4	5	N/A
Unidentified small whale	Cetacean sp.	1	1	N/A
Unidentified dolphin	Delphinidae sp.	3	8	2 - 5
Total number of sightings			92	
Total number of individuals			944	

Table 7. Sightings summary of other marine fauna.

Species common name	Scientific name	No. of sightings	No. of animals	Group size range
Bluefin tuna	*Thunnus thynnus*	22	107	4 - 15
Albacore tuna	*Thunnus alalunga*	1	3	N/A
Grey seal	*Halichoerus grypus*	1	1	N/A
Tuna sp.	Thunnus sp.	55	180	3 - 12
Seal sp.	Phocidae sp.	1	1	N/A
Total no. of sightings			80	
Total no. of individuals			292	

Table 8. Totals for all seabird species recorded.

Vernacular name	Scientific name	On survey	Off survey	Total
European Storm-petrel	*Hydrobates pelagicus*	5	0	5
Fulmar	*Fulmarus glacialis*	84	0	84
Great Shearwater	*Ardenna gravis*	3	0	3
Sooty Shearwater	*Ardenna grisea*	20	0	20
Manx Shearwater	*Puffinus puffinus*	37	0	37
Unidentified Shearwater		0	15	15
Gannet	*Morus bassanus*	1205	728	1933
Shag	*Phalacrocorax aristotelis*	3	0	3
Cormorant	*Phalacrocorax carbo*	1	0	1
Kittiwake	*Rissa tridactyla*	208	175	383
Sabines Gull	*Xemi sabini*	2	0	2
Black-headed Gull	*Chroicocephalus ridibundus*	1	0	1
Mediterranean Gull	*Ichthyaetus melanocephalus*	2	0	2
Common Gull	*Larus canus*	4	0	4
Great Black-backed Gull	*Larus marinus*	193	202	395
Herring Gull	*Larus argentatus*	41	44	85
Lesser Black-backed Gull	*Larus fuscus graellsii*	31	47	78
Unidentified Gull		21	48	69
Sandwich Tern	*Thalasseus sandvicensis*	1	0	1
Common Tern	*Sterna hirundo*	2	0	2
Great Skua	*Stercorarius skua*	41	3	44
Arctic Skua	*Stercorarius parasiticus*	1	0	1
Guillemot	*Uria aalge*	1421	27	1448
Razorbill	*Alca torda*	114	3	117
Guillemot/ Razorbill		341	0	341
Puffin	*Fratercula arctica*	22	0	22
Unidentified Auk		1	0	1
Total		3805	1292	5097

Table 9. Totals of migrant terrestrial bird species recorded.

Vernacular name	Scientific name	Total
Grey Heron	*Ardea cinerea*	1
Rock Dove	*Columba livia*	1
Merlin	*Falco columbarius*	1
Chiffchaff	*Phylloscopus collybita*	1
Starling	*Sturnus vulgaris*	2
Fieldfare	*Turdus pilaris*	1
Black Redstart	*Phoenicurus ochruros*	1
Grey Wagtail	*Motacilla cinerea*	1
Pied Wagtail	*Motacilla alba*	1
Chaffinch	*Fringilla coelebs*	1
Linnet	*Linaria cannabina*	1
Wheatear	*Oenanthe oenanthe*	1
Unidentified Passerine		3
Total		16

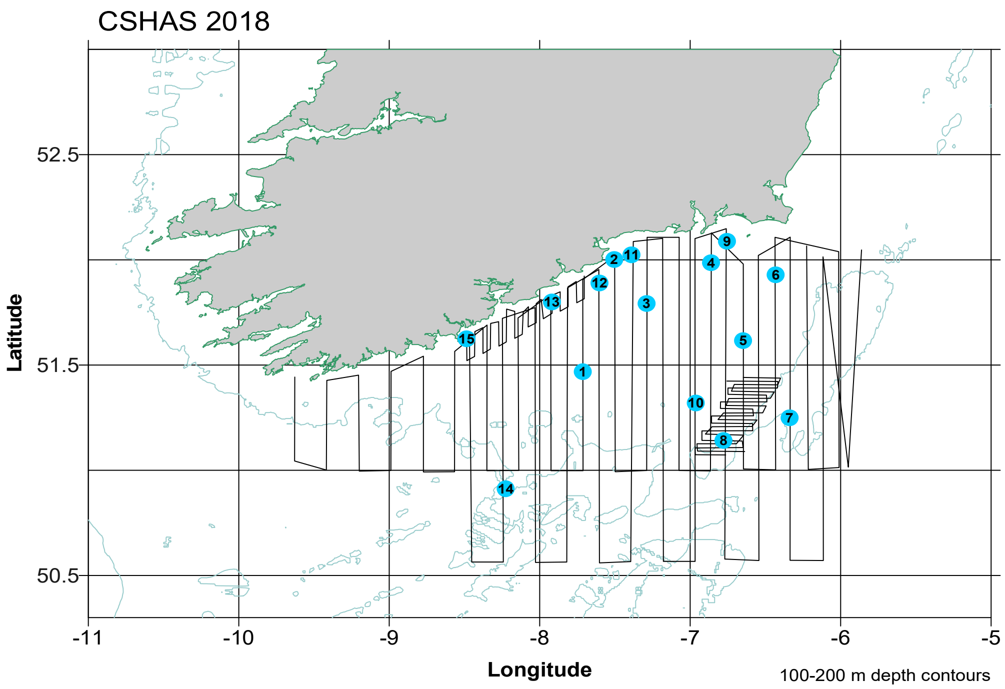


Figure 1. Survey cruise tracks for core and adaptive surveys and pelagic trawl positions by numbered station.

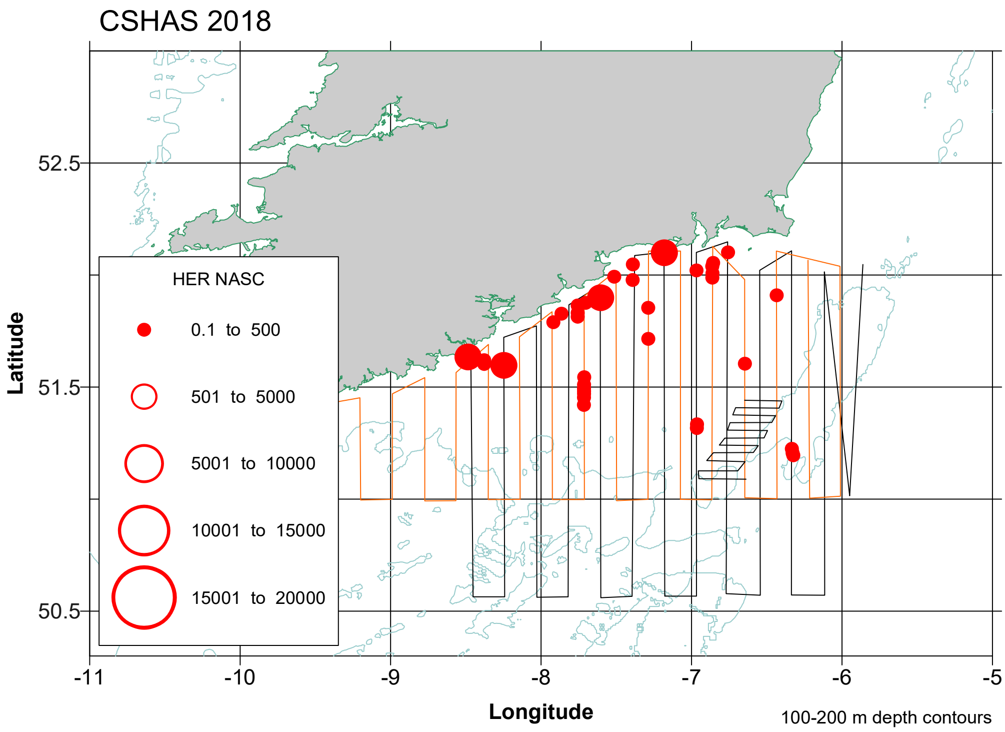


Figure 2. Herring NASC (Nautical area scattering coefficient) plot of herring distribution from replicate core survey effort. Pass 1; black track, Pass 2; orange track.

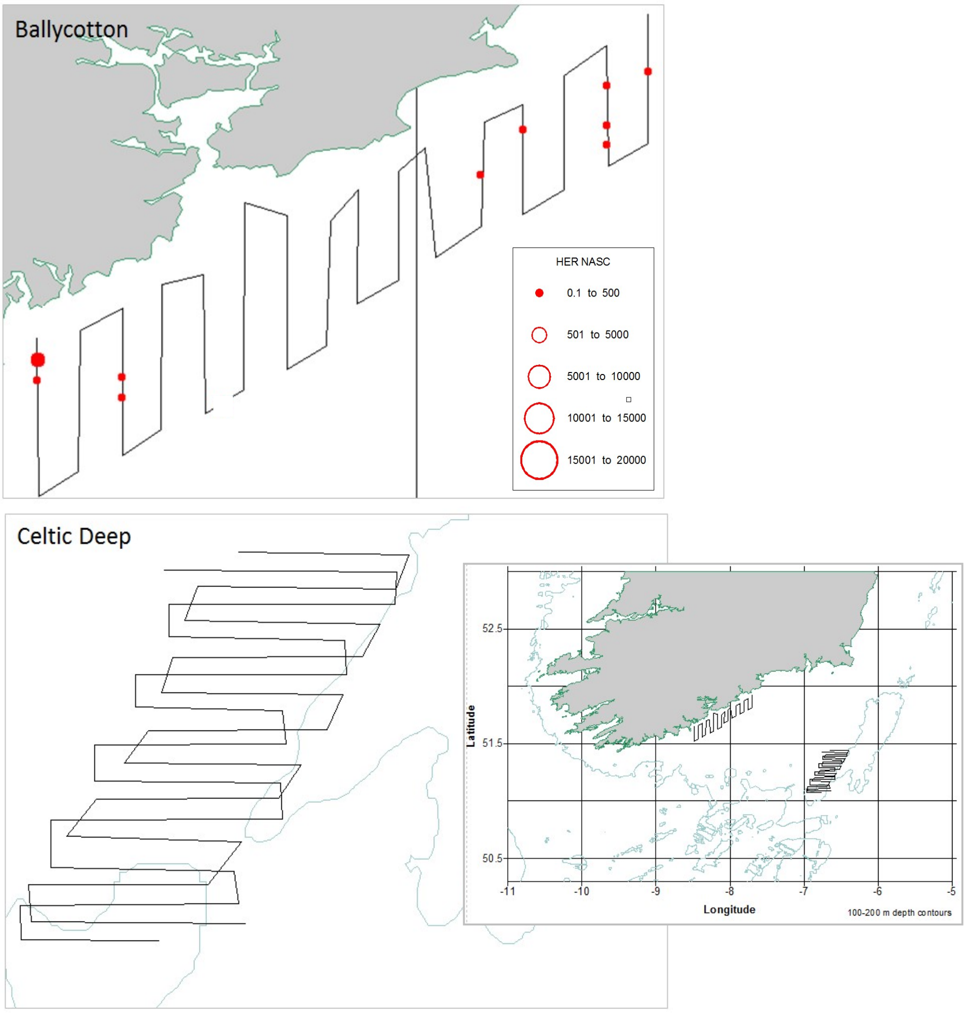


Figure 3. Herring NASC (Nautical area scattering coefficient) plot of the distribution from adaptive survey effort. Top Panel: coastal area; bottom panel: offshore area (no herring).

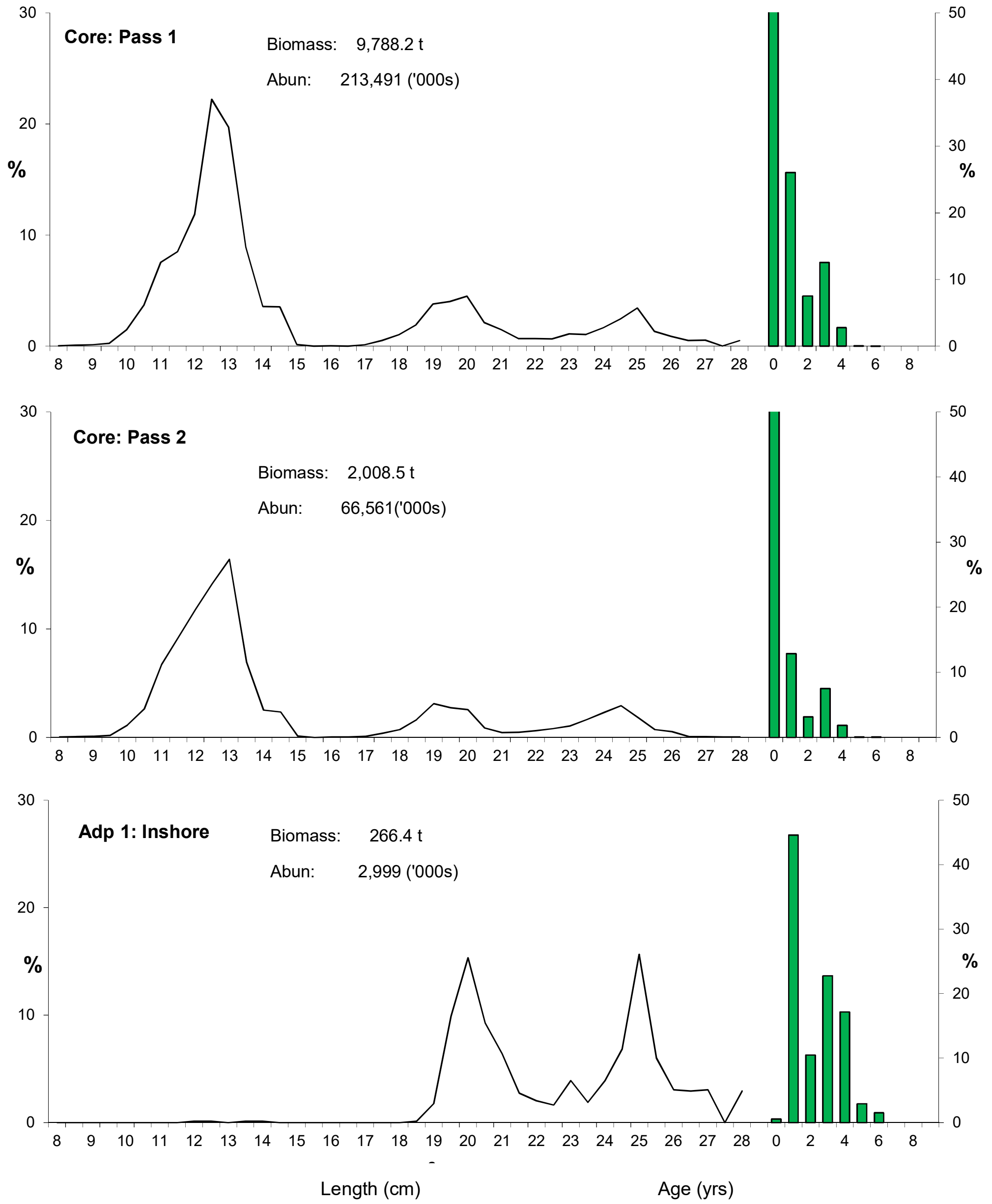


Figure 4. Age and length composition of herring from core and adaptive survey strata.

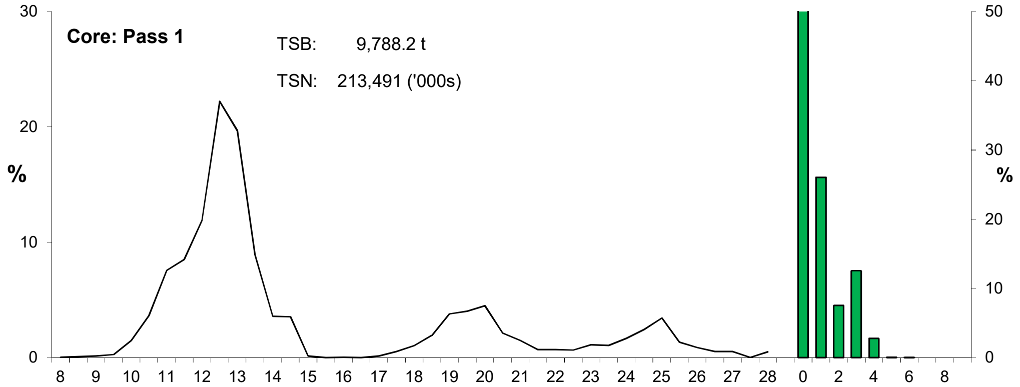


Figure 5. Age and length composition of 2018 stock estimate based on largest stratum area surveyed; Core survey Pass 1.

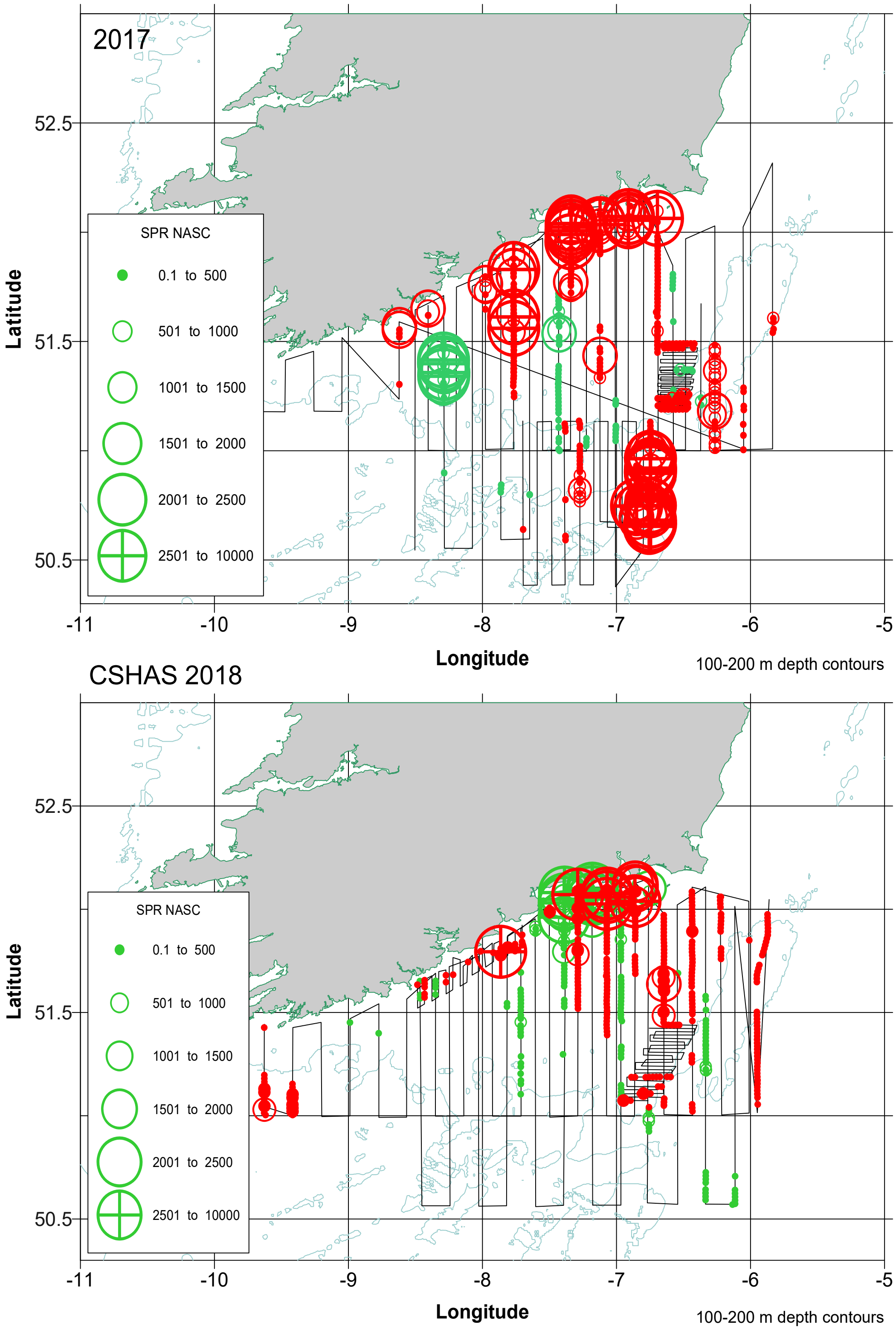


Figure 6. Sprat NASC (Nautical area scattering coefficient) plot of the distribution from replicate core survey effort. Green indicates Pass1 observations and red indicates Pass 2.

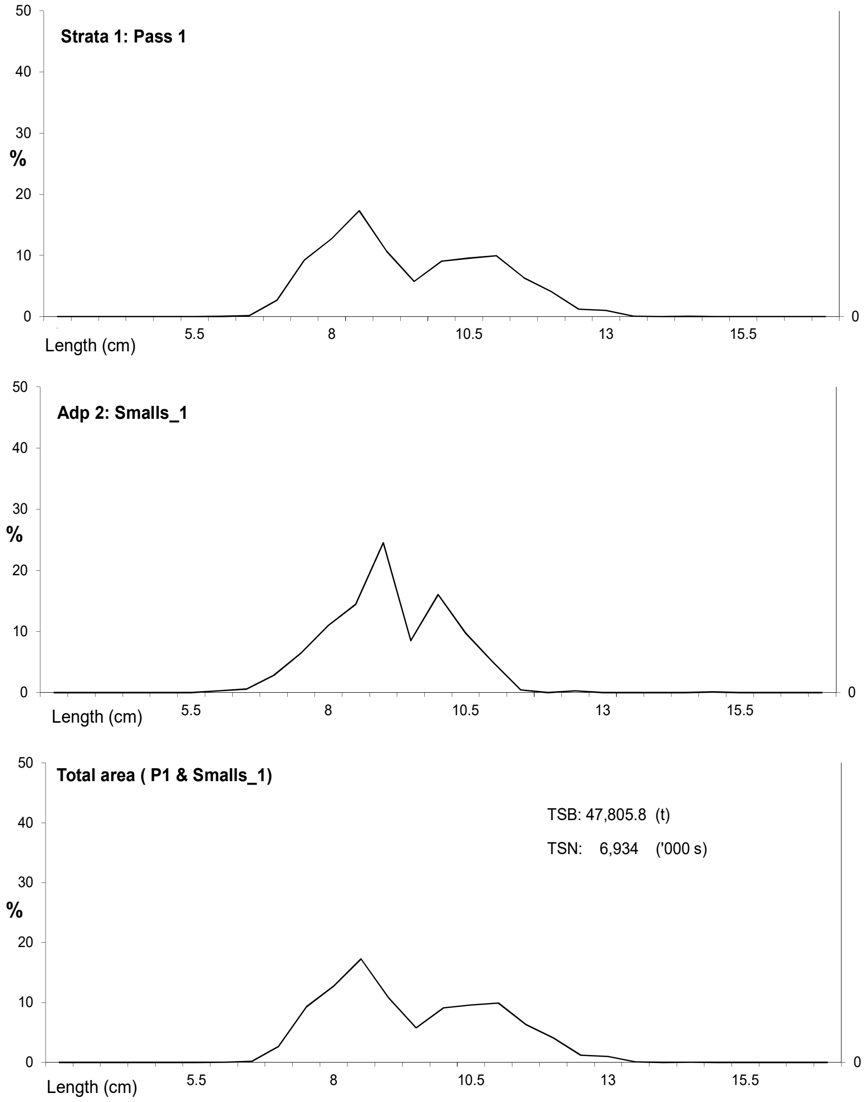
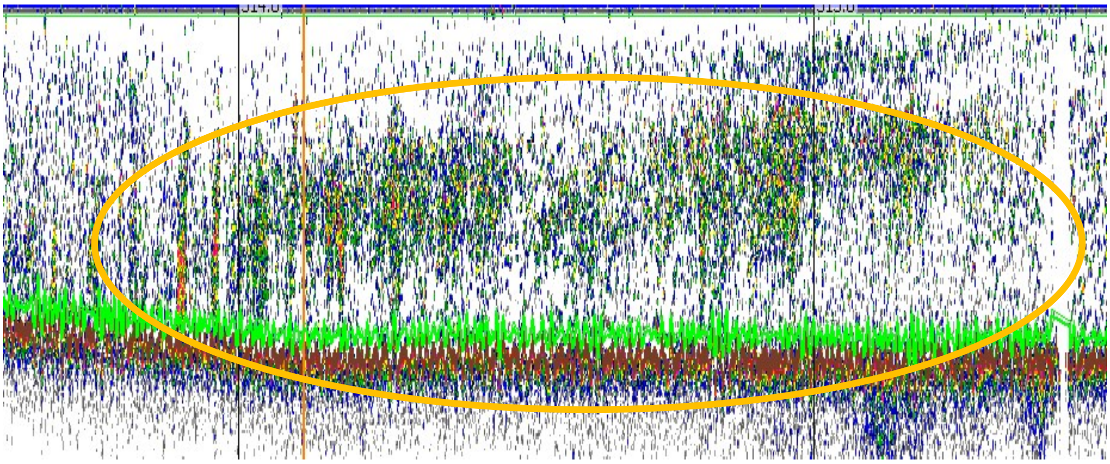
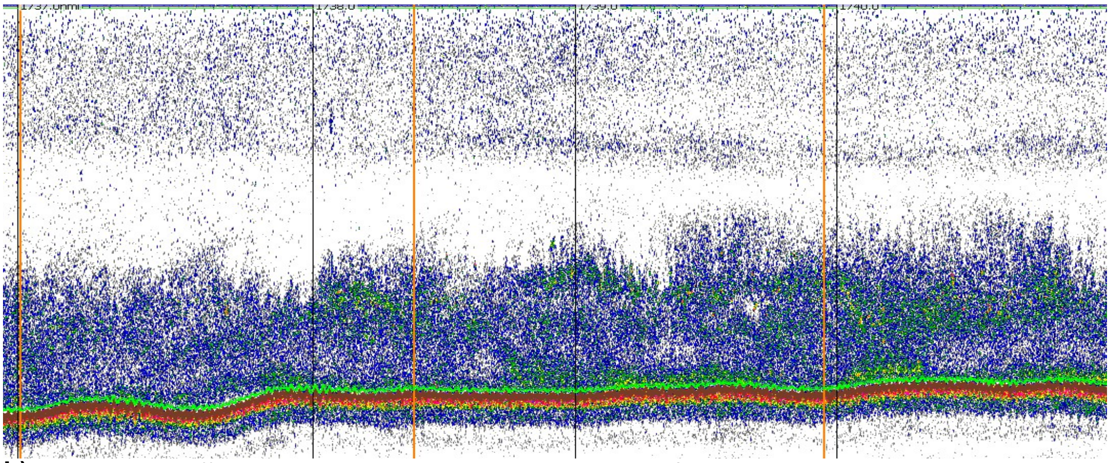


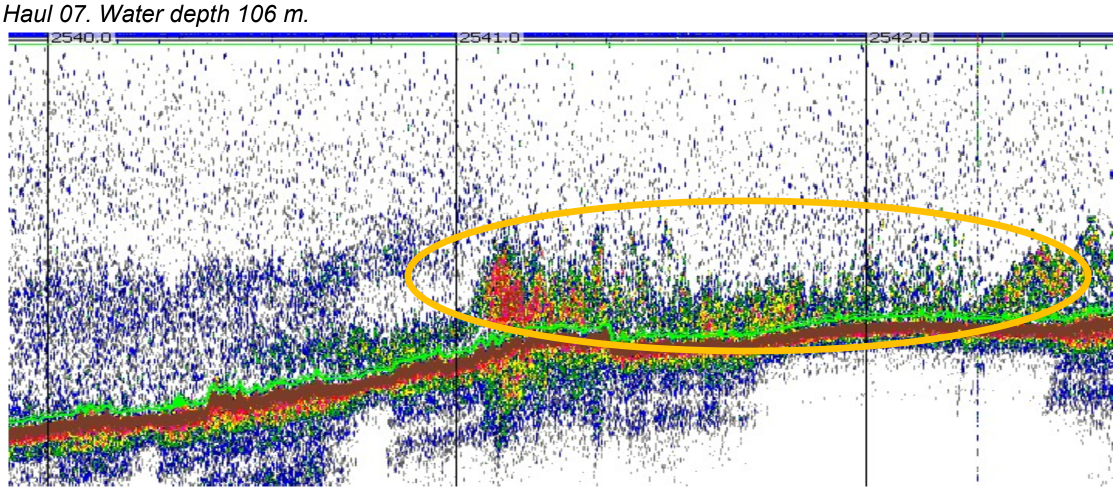
Figure 7. Length composition of sprat by strata and combined survey effort.



a). *Low density echotrace containing <1% herring observed at night prior to Haul 02. Recorded inshore during Pass 2. Water depth 36 m*

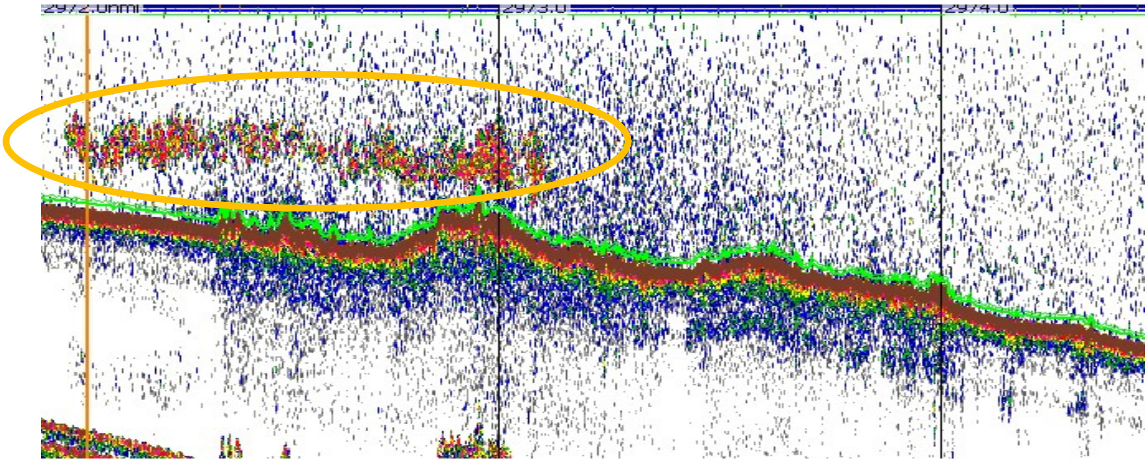


b). *Low density offshore sprat scattering layer containing 26% herring observed during daytime prior to Haul 07. Water depth 106 m.*

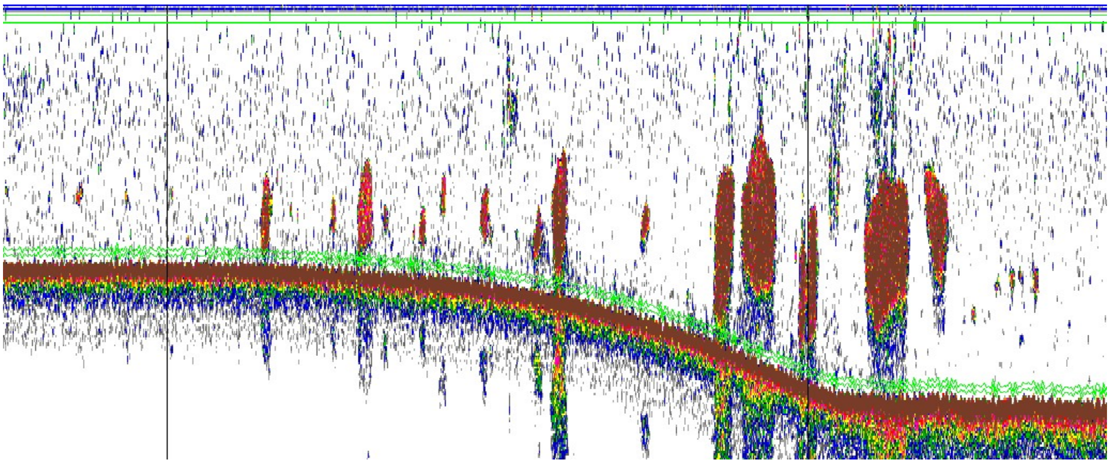


c). *Medium density echotrace containing 80% herring by weight, observed during the daylight prior to Haul 12. Recorded offshore during Pass 1. Water depth 54 m.*

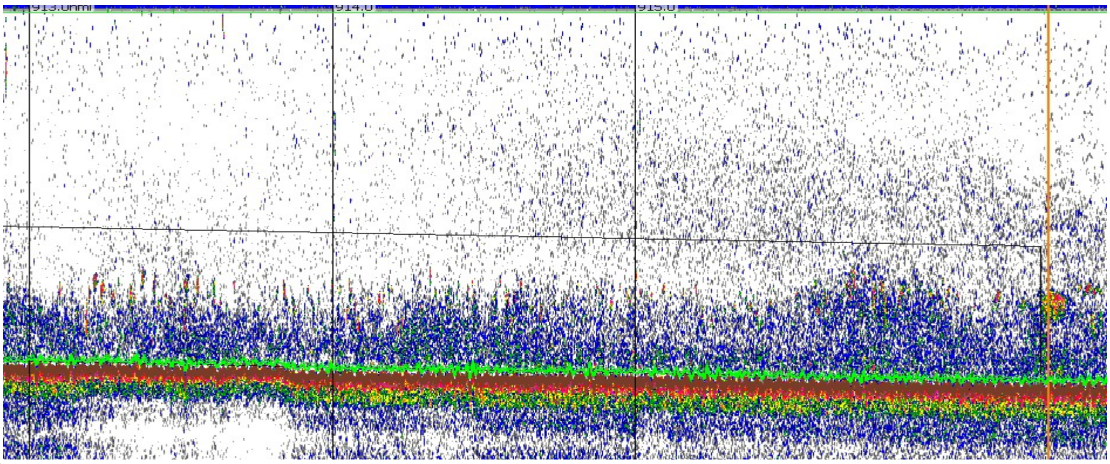
Figure 8. EK60 echograms (38 kHz) recorded prior to directed trawl stations.



d). *Medium density seabed echotrace containing herring (65%), pilchard sprat and mackerel, observed inshore during an adaptive survey, early morning prior to Haul 15. Water depth 42 m.*

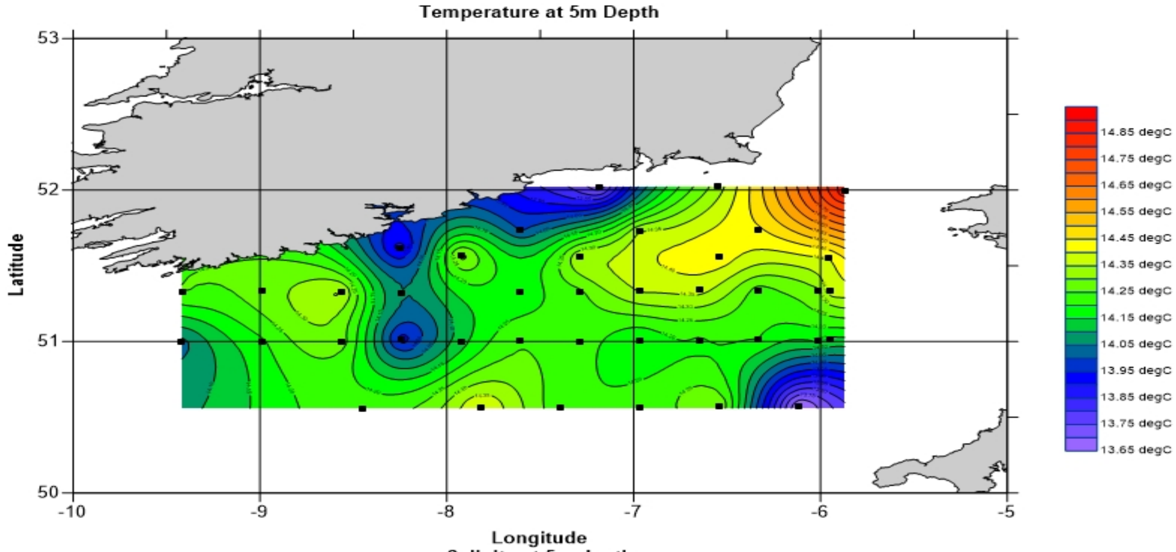


e). *High density sprat echotrace inshore south of Waterford. Haul 09, day time. Water depth 30 m.*



f). *Low density mix species (sprat 80%) echotrace recorded offshore during day light prior to Haul 05. Water depth is 70 m*

Figure 8a-f. Continued



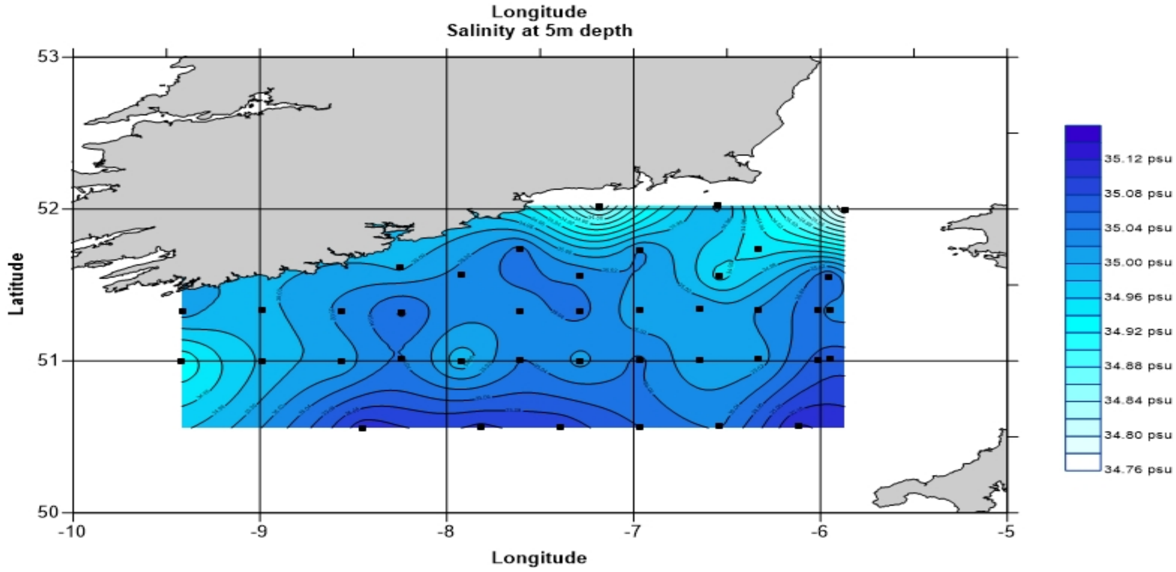


Figure 9. Surface (5 m) plots of temperature and salinity compiled from CTD cast data. Station positions shown as black circles (n=40).

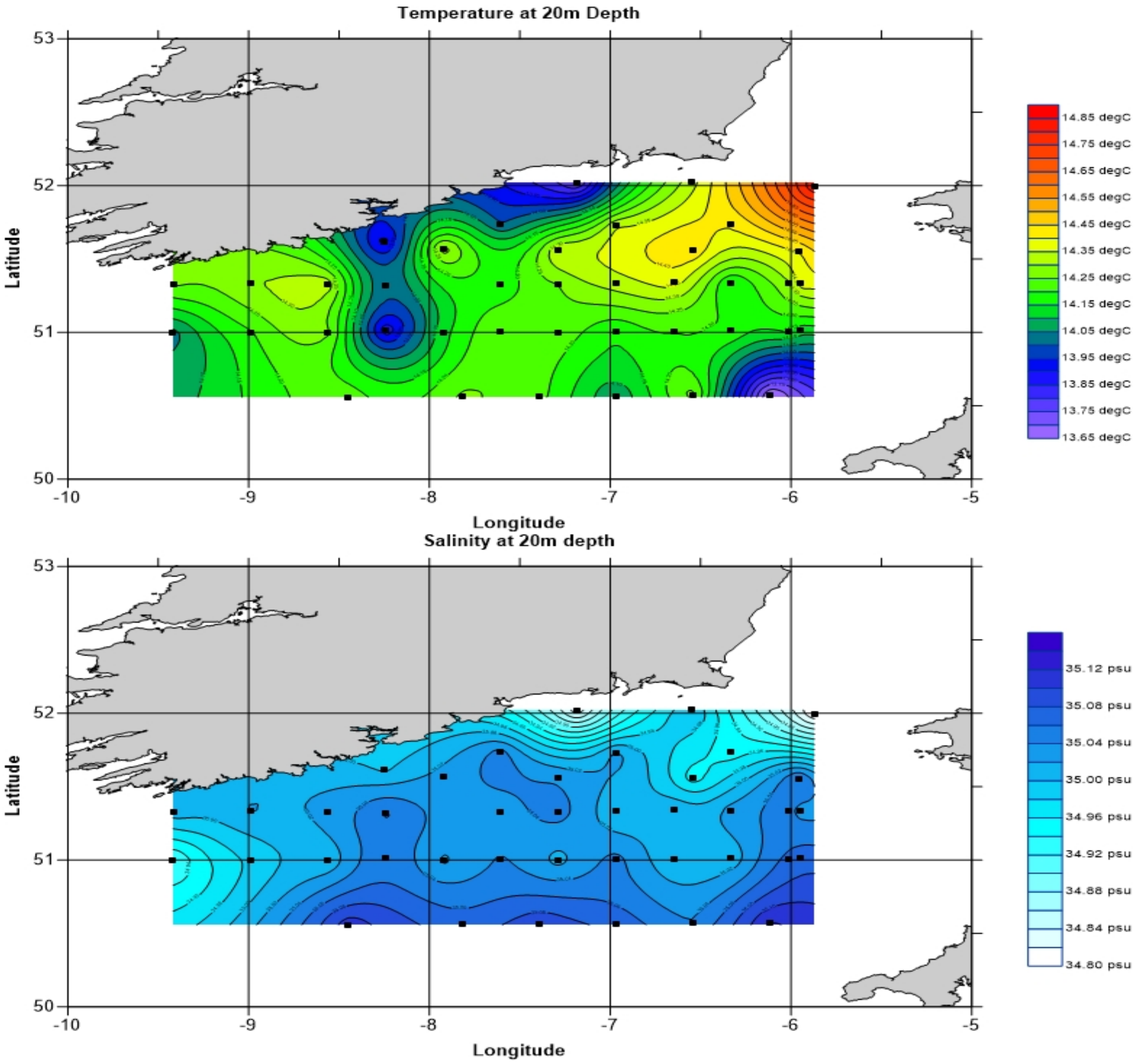


Figure 10. Surface (20 m) plots of temperature and salinity compiled from CTD cast data. Station positions shown as black circles (n=40).

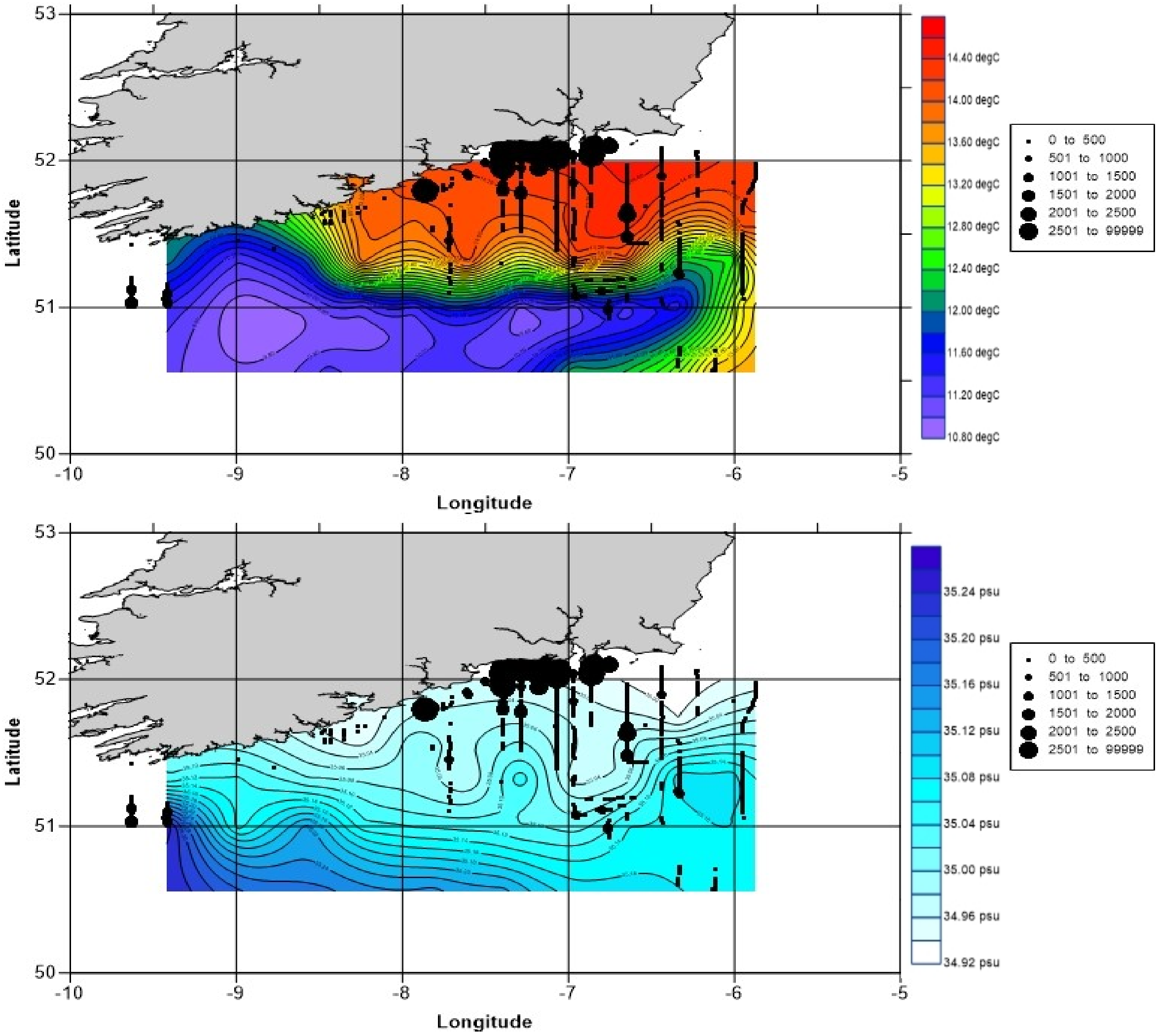


Figure 11. Habitat plots of temperature and salinity at 60 m overlaid with sprat NASC values (black circles).

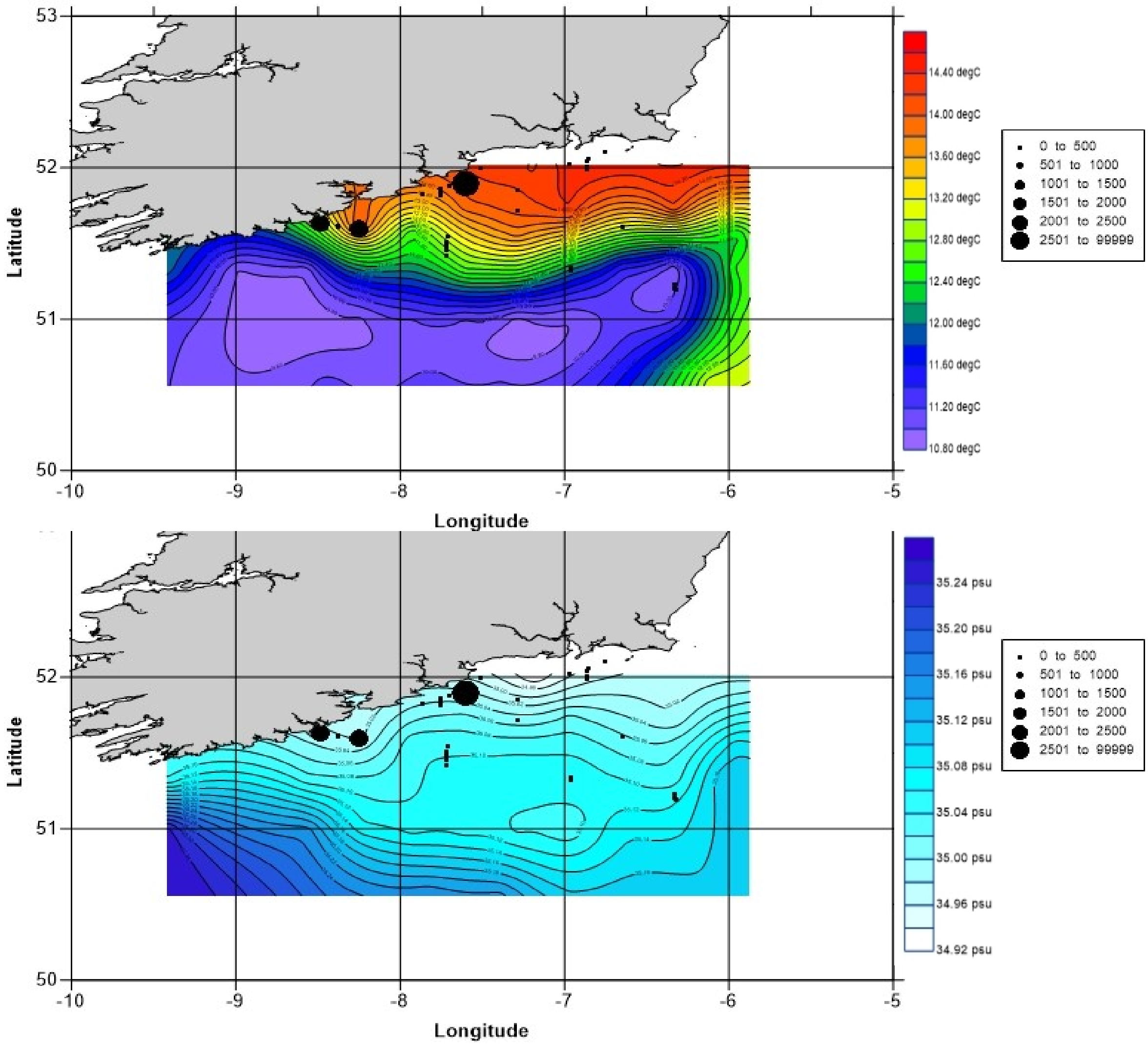


Figure 12. Habitat plots of temperature and salinity at the seabed overlaid with herring NASC values (acoustic density) shown as black circles.

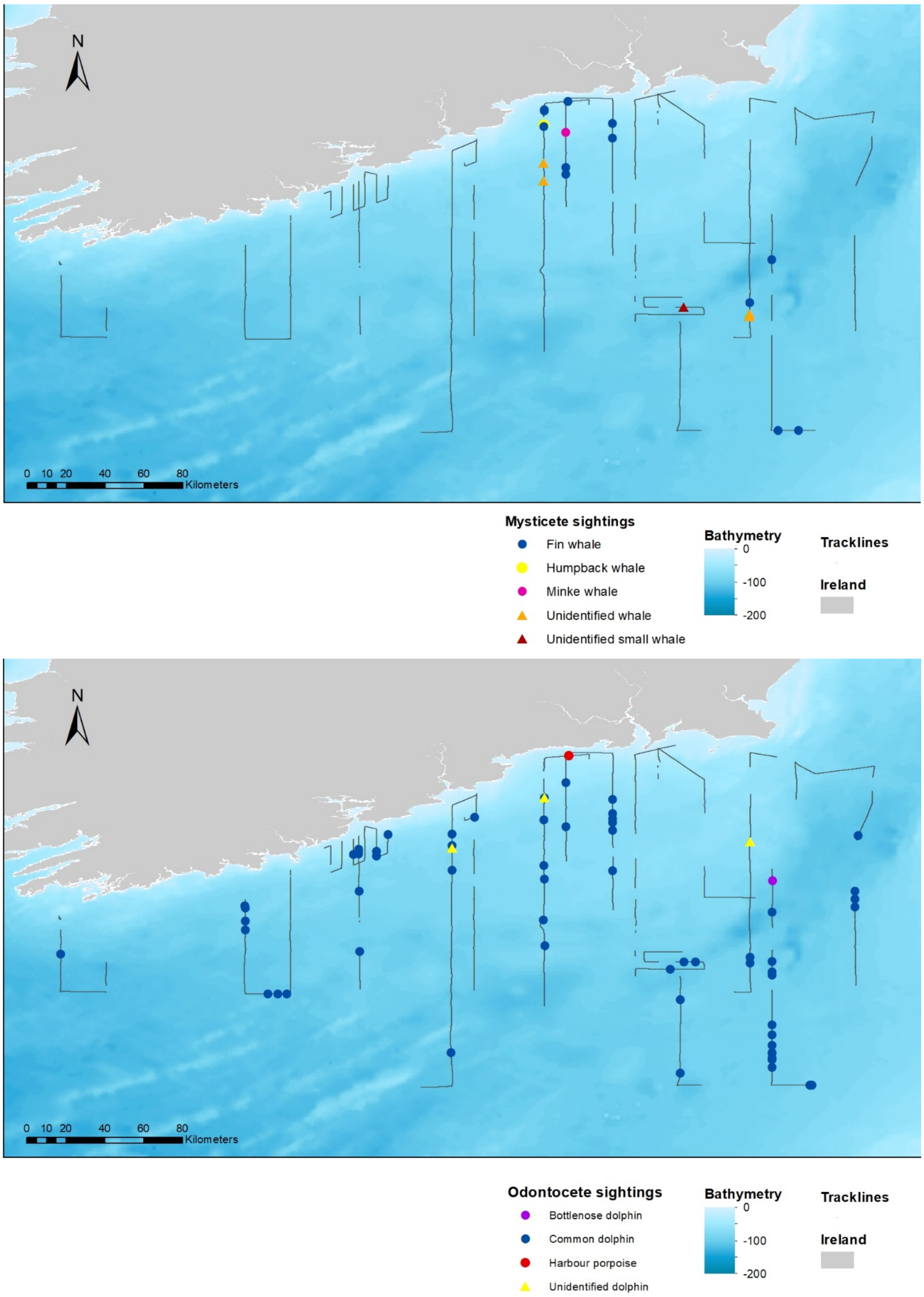


Figure 13. Visual survey effort derived distribution map of whales (top panel) dolphin species (btm panel).

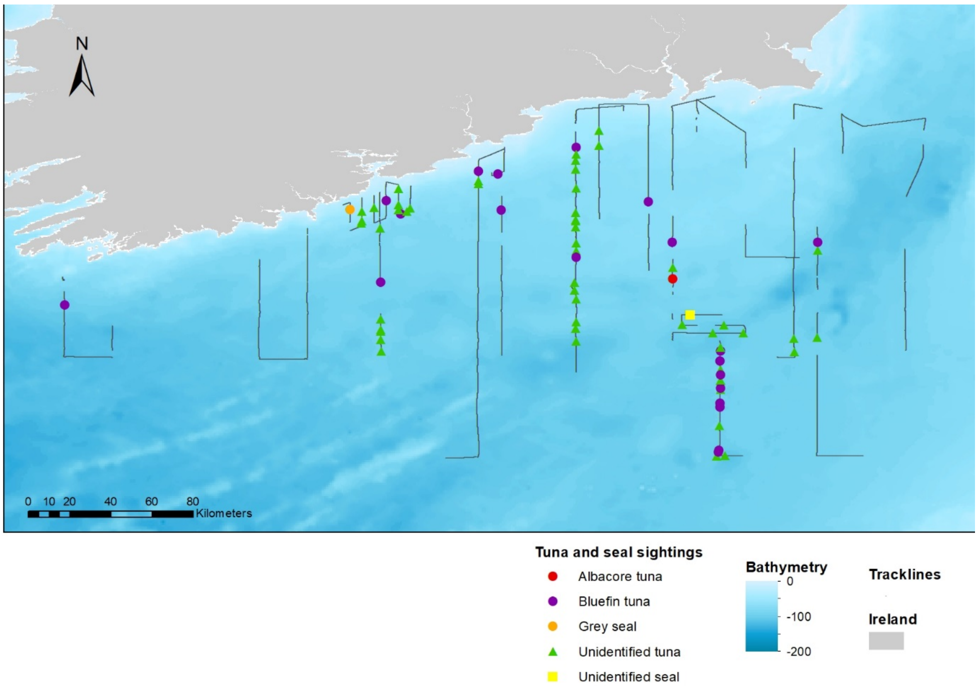


Figure 14. Visual survey effort derived distribution map of megafauna.

HERRING MIDWATER TRAWL

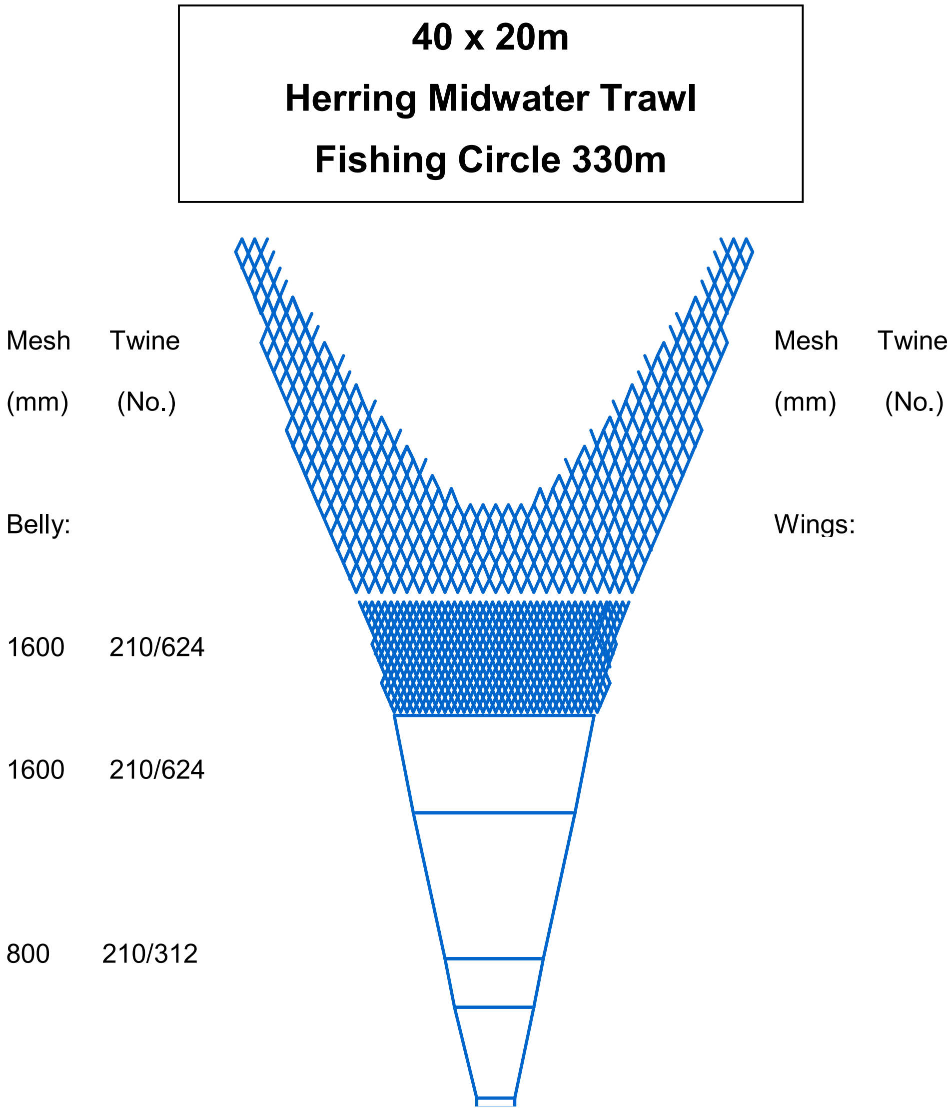


Figure 15. Single herring midwater trawl net plan and layout. Celtic Sea herring acoustic survey.

Note: All mesh sizes given in half meshes; schematic does not include 32m brailer. Centred

8 Appendix

	Age (years)										Numbers	Biomass	Mn Wt	Mature
(cm)	0	1	2	3	4	5	6	7	8	9	(*10-³)	(t)	(g)	(%)
8	54										98	0.2	4	0.0
8.5	108										197	0.4	4	0.0
9	161										293	1.3	8	0.0
9.5	323										588	1.9	5.83	0.0
10	1747										3181	11.3	6.49	0.0
10.5	4297										7825	32.7	7.61	0.0
11	8864										16140	74.9	8	0.0
11.5	9963										18141	98.1	10	0.0
12	14102										25395	154.6	11	0.0
12.5	26126										47459	325.9	12	0.0
13	23454										42035	331.9	14	0.0
13.5	10612										19041	165	16	0.0
14	4264										7649	73.8	17	0.0
14.5	4149										7556	79.1	19	0.0
15	192										349	4.4	23	0.0
15.5												0		0.0
16	53										97	1.2	22	0.0
16.5	110										33	2.5	23	0.0
17	161										293	6.8	42	0.0
17.5		799									1119	32.1	40	100.0
18		1332									2257	58	43.54	50.0
18.5		3797									4109	174.2	45.86	30.0
19		8238									8119	407.5	49.46	66.7
19.5		11805									8603	620.1	52.53	65.4
20		14846	524								9639	879.7	57.24	73.3
20.5		8020	624								4531	536.5	62.06	84.6
21		3556	1819								3189	347.4	64.62	100.0
21.5		2068	1128								1495	215.7	67.47	100.0
22		762	2476								1476	246.3	76.06	100.0
22.5		397	3178								1427	301.8	84.39	100.0
23			3942								2389	385.7	97.84	100.0
23.5			1255	5227							2283	672.9	103.81	100.0
24			214	7698							3564	900.1	113.76	100.0
24.5			745	7024	2128						5216	1185	119.73	100.0
25			199	5473	697						7363	817.9	128.44	100.0
25.5				902	1504						2863	321.5	133.58	100.0
26				506	1013		101				1881	217.5	134.25	100.0
26.5					221						1129	27.4	124	100.0
27					311						1179	42	135	100.0
27.5					110						33	17.6	160	100.0
28						110					1097	15.6	141	100.0
TSN (*10-³)	1E+05	55621	16104	26831	5984	110	101				213491			
TSB (t)	1366	3107	1341	3172	775.1	15.6	11.9					9788.2		
Mean length (cm)	12.44	19.8	22.37	24.33	25.32	28	26							
Mean weight (g)	12.56	55.85	83.29	118.2	129.5	141	118						45.85	
% Mature	0	72	99	100	100	100	100							
SSB (t)	0.0	2444.7	1341.3	3171.8	775.1	15.6	11.9				7760.4			

Figure 1. Biomass and abundance at length and age for Core survey: Pass 1.

	Age (years)										Numbers	Biomass	Mn Wt	Mature
(cm)	0	1	2	3	4	5	6	7	8	9	(*10-³)	(t)	(g)	(%)
8	20										20	0.081	4	0.0
8.5	41										41	0.2	4	0.0
9	61										61	0.5	8	0.0
9.5	121										121	0.7	6	0.0
10	759										759	4.9	6	0.0
10.5	1752										1752	13.1	7	0.0
11	4461										4461	37.6	8	0.0
11.5	6143										6143	60.2	10	0.0
12	7851										7851	86.4	11	0.0
12.5	9444										9444	117.8	12	0.0
13	10932										10932	154.3	14	0.0
13.5	4620										4620	71.7	16	0.0
14	1671										1671	28.8	17	0.0
14.5	1559										1559	29.7	19	0.0
15	72										72	1.7	23	0.0
15.5											0	0	0	0.0
16	20										20	0.4	22	0.0
16.5	23										23	0.5	23	0.0
17	60										60	2.5	42	0.0
17.5		263									263	10.6	40	100.0
18		482									482	21.1	43.69	50.0
18.5		1098									1098	50.2	45.75	30.0
19		2064									2064	102	49.4	66.7
19.5		1819									1819	95.4	52.44	65.4
20		1658	48								1707	98.1	57.5	73.3
20.5		528	41								569	35.2	61.84	84.6
21		213	81								294	19.1	65.02	100.0
21.5		186	115								300	20.2	67.24	100.0
22		170	243								412	31.3	75.82	100.0
22.5		74	457								531	44.8	84.33	100.0
23			691								691	67.6	97.84	100.0
23.5			88	1006							1094	114.7	104.84	100.0
24			82	1437							1519	172.2	113.32	100.0
24.5			187	1268	478						1934	231.5	119.71	100.0
25			75	991	131						1197	153.1	127.84	100.0
25.5				161	322						483	64.7	133.92	100.0
26				133	199		22				354	47.3	133.62	100.0
26.5					46						46	5.7	124	100.0
27					46						46	5.8	126	100.0
27.5					23						23	3.7	160	100.0
28						23					23	3.2	141	100.0
TSN (*10-³)	49611	8554	2108	4997	1246	23	22				66561			
TSB (t)	611	453	188.6	589.1	160.8	3.2	2.6					2008.5		
Mean length (cm)	12.37	19.42	22.76	24.33	25.27	28	26							
Mean weight (g)	12.32	52.95	89.47	117.9	129.1	141	118						30.17	
% Mature	0	67	99	100	100	100	100							
SSB (t)	0.0	340.1	188.6	589.1	160.8	3.2	2.6				1284.4			

Figure 2. Biomass and abundance at length and age for Core survey: Pass 2.

	Age (years)										Numbers	Biomass	Mn Wt	Mature
(cm)	0	1	2	3	4	5	6	7	8	9	(*10-³)	(t)	(g)	(%)
8														0
8.5														0
9														0
9.5														0
10														0
10.5														0
11														0
11.5														0
12	4										4	0.041	10	0
12.5	4										4	0.049	12	0
13											0			0
13.5	4										4	0.065	16	0
14	4										4	0.074	18	0
14.5														0
15														0
15.5														0
16														0
16.5														0
17														0
17.5														0
18														0
18.5		4									4	0.2	44	30
19		53									53	2.6	48	67
19.5		297									297	16.1	54	65
20		460									460	27.3	59	73
20.5		257	20								278	17.3	62	85
21		127	65								192	12.4	65	100
21.5		82									82	5.7	69.6	100
22		37	25								61	4.7	77.47	100
22.5		20	29								49	3.9	79.5	100
23			117								117	10.5	90	100
23.5				57							57	6	105.14	100
24			58	58							117	11.6	99.5	100
24.5				205							205	19.9	96.89	100
25				196	274						470	59.4	126.5	100
25.5				120	60						180	23.9	132.67	100
26				46			46				92	12	130	100
26.5					88						88	10.9	124	100
27					92						92	10	108	100
27.5														0
28						88					88	11.8	134	100
TSN (*10-³)	16	1337	314	683	515	88	46				2999			
TSB (t)	0.2	80.5	25.5	79.6	63.4	11.8	5.4					266.4		
Mean length (cm)	13	20.22	22.48	24.79	25.67	28	26							
Mean weight (g)	14	60.23	81.08	116.5	123.1	134	118						88.84	
% Mature	0	83	100	100	100	100	100							
SSB (t)	0.0	68.0	25.5	79.6	63.4	11.8	5.4				253.7			

Figure 3. Biomass and abundance at length and age for Adaptive survey: Inshore.